THE

CABINET OF USEFUL ARTS.

CONDUCTED BY THE

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ASSISTED BY

EMINENT SCIENTIFIC MEN.

DOMESTIC ECONOMY.

VOL. I.

BREWING. | WINE MAKING.
DISTILLING | BAKING, &c.

BY

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ADVERTISEMENT.

The reader will easily perceive that the processes described in this treatise have been derived from actual inspection. They are the result of a comparison of the practices adopted at various establishments; and no means were spared to procure access to those of which the produce evinced the superiority. Obstacles are to be encountered in obtaining an acquaintance with the operations of great manufactories. Merely to obtain admission is not easy; and to be permitted to inspect the process repeatedly in all its stages evinces more than common liberality on the part of the proprietor. To learn the manipulative parts in which concealments are attempted can scarcely be effected with certainty. Such knowledge can only be obtained from those whose necessities compel them to make sale of it; and who, after all, are seldom capable of communicating what they know in such a manner as will render their skill available, without great trouble to the enquirer. Judgment must be used in the selection and application of information thus acquired: amongst operatives, long habit creates certainty; what they have always done, they naturally believe to be right; and success or failure may

depend upon so many causes, that even extensive experience does not enable them to distinguish whether any particular practice is well or ill founded.

These difficulties occasion the discordances which so often occur in the accounts given of the same subject by different observers. Technological treatises in Encyclopædias, which are always expected to connect theory with practice, and which are therefore generally written by scientific men instead of the actual operator, are thus frequently found contradictory in their own parts on account of the peculiar circumstances under which information is derived. Owing to the same causes, we find them sometimes written with such caution, that controverted topics are evaded instead of being decided, or even discussed. With the hope of lessening the number of such defects in the present undertaking I have used all diligence in seeking information, not from written authorities alone, but also from the best practical sources, aided by numerous experiments made by myself at intervals during the last twelve years. Sometimes these experiments were made on the scale on which the manufacturer himself works, they having been conducted in his manufactory, and with the assistance of his knowledge and experience. Risks on such a scale will seldom be incurred voluntarily by persons whose property is at stake; but there are cases in which, to avoid certain losses, the danger of possible ones must be encountered. Under such circumstances, I have had extensive opportunities of making observations. The facilities which my profession offered, and the processes of my own laboratory, afforded me some of the necessary information.

Conformably with the views of the conductor of this Cyclopædia, I have endeavoured to render my explanations of processes complete in themselves, and as little as possible dependant on the pre-supposed scientific acquirements of the reader. With a moderate share of general information, and occasional reference to any elementary work on chemistry, I trust that the following treatise will be intelligible, and that it may attain the ends proposed in the work of which it forms a part, by diffusing a knowledge of processes in which every consumer of the most ordinary articles of food and drink is directly interested.

It must, however, be observed, that to arrive at extensive and accurate practical knowledge in the arts here treated of it will be necessary first to have acquired a competent knowledge of chemistry. Want of such knowledge creates a timidity in conducting great and expensive processes, which is the most effectual obstacle to improvement. The routine which previous custom has sanctioned is still followed: the fear of failure forbids any departure from it. New discoveries are not applied, because they are not appreciated; and error is perpetuated because its sources are concealed by ignorance.

A reader acquainted with the large works which have been written on these subjects may be inclined to suppose that the general principles of each cannot be included in an extent so limited. This would certainly have been the case, if means had not been adopted to remove such an objection. The means used are simply condensation. It will be found that the quantity of matter introduced might easily have been expanded into twice the bulk, by merely rendering the style more diffuse; this, however, would not have accorded with

the plan of the Cabinet Cyclopædia. I venture to hope, that much more than the general principles of each art will be found here detailed; and that the quantity of materials, condensed as they are, will bear comparison with those contained in works of greater magnitude.

Dublin, Jan. 1. 1830

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DOMESTIC ECONOMY.

VOLUME THE FIRST.

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INTRODUCTION.

The subjects of the following pages are those processes in domestic economy which are founded on or connected with fermentation. They are all naturally associated with each other, either by similarity of the ingredients concerned, or of the operations to which they are subjected. Thus when grain is malted, we may obtain from it either yest, sugar, beer, alcohol, or vinegar. Beside the connection, in this case established by identity of material, the processes by which the different products are obtained are further connected by the fermentation that gives origin to them all. The consideration of malt implies that of its original form, grain, and of the constituents of the flour obtained from grain. We have also to study the mechanism of the seed which occasioned the surprising change of one of its principles into a substance essentially different. The flour, even without having been malted, and whether obtained from grain or from the potato, may be made into bread, starch, sugar, beer, alcohol, or vinegar. From the juice of fruits we obtain the same products as from malt, viz. yest, sugar, beer, alcohol, or vinegar. Malt and fruits, whatever may be the apparent disparity between them, are therefore nearly related to each other, and should be treated of in subdivisions of the same general head. Vinegar and a species of alcoholic liquor

may be obtained by means so different from fermentation, that it is really surprising how processes so dissimilar can terminate in the same results: by the distillation of wood they are obtained in abundance. This process, therefore, though totally unconnected in its nature with fermentation, becomes intimately associated with that phenomenon by the similarity of its products: and hence, in the description of one, an account of the other should not be neglected.

For these reasons, I have taken a little latitude in the selection of the subjects, and in their arrangement. I have not treated exclusively of any particular class of phenomena, nor of any particular class of bodies obtained by related processes. But I have brought together some subjects which common sense points out as practically connected with and illustrative of each other.

The subjects and arrangement of the volume will be as follow: First, the *constitution of seeds* in general will be described. Next, the changes which they undergo in *germination*, or, as it may be otherwise expressed, in *malting*. Afterwards come the uses to which malt is applied in domestic and public *brewing*, in *yest making*, and in *distillation*. Then will be detailed the processes for preparing *wines*, both foreign and domestic. *Vinegar making* will then come under consideration; and the different sources from which vinegar is economically procured will be pointed out. Lastly, the art of *bread making* will be briefly described; it being a process as much founded on fermentation as brewing or distilling.

Beside these details, an account of all the substances employed in the different departments will be given. And although the subject of *fermentation* will be found in the volume of the Cyclopædia allotted to Chemistry, it will be here considered, both in theory and practice; but in such a way as is peculiarly required for the purposes of a treatise of this kind. A sketch of the *history of intoxicating liquors* commences the work.

CHAP. I.

SKETCH OF THE HISTORY OF INTOXICATING LIQUORS.

In all ages, and amongst all nations, methods have been known of exciting certain pleasurable sensations of the mind, derived from artificial sources. Civilization has not to answer for the offence of instructing mankind in the art of producing these depraved conditions of the human intellect, although it has disclosed more extended means of so doing: for the most savage nations have been found in possession of the secret. The methods, indeed, are so various, and sometimes so obvious, that it would be singular if, even in the early ages of the world, opportunities did not occur of experiencing the wonderful effects of these natural or artificial narcotics. These effects, so delightful to the savage state, once experienced, and the mode of producing them at will once ascertained, the discovery would be treasured up and transmitted to posterity as a fact of the utmost importance to the condition of mankind; — as a talismanic controller of perceptions and ideas, adding acuteness to the former, and vividness to the latter; or else extinguishing all sense and power of motion in a state which encroaches beyond the boundaries of sleep, and approaches somewhat towards the oblivion of death.

Numerous have been the means discovered and resorted to of accomplishing these objects, the diversity originating in the circumstances of the case. In some countries, the grape and other fruits afforded an easy and obvious method of attaining intoxication to any required degree. In other parts, a wine made from grain answered as effectually. Where these means were not so readily attainable, perverted ingenuity discovered that the mildest and most nutritious of all liquors, milk, could be converted into this debasing poison. Sometimes nature presented the means when art was deficient; and vege-

table poisons were so modified, or used in such quantity, as to produce the first stage only of the mischief. Such substances have been much in request, even amongst comparatively civilized nations, whose religious tenets imposed restrictions on the use of inebriating liquors, produced by fermentation: the letter, but not the spirit, of the law was complied with. It is singular to contemplate, how differently the use of intoxicating liquors has been viewed in creeds promulgated in barbarous ages: the Koran rigidly prohibits the use of them; but the Edda declares it to be an heroic virtue to drink much liquor. Before the conversion of the ancient Scandinavians to Christianity, they believed that one of the chief sources of happiness in the hall of Odin was excessive indulgence in beverages of this kind.

Opium is the well-known resource of the Mahometans; and unfortunately is not altogether unknown in Britain. In small quantity, seldom employed, it produces serenity of mind and pleasurable sensations: it inspires animal courage and animal desires: and from the latter quality arises its use as a habit in countries where polygamy is permitted. A practice of the Turks was to swallow the bulk of a hazel-nut of opium when going to battle, with the view of inspiring courage.

Those unfortunate persons in this country, who, through irritability of temperament and proneness to despondency, betake themselves to the dreadful practice of opium eating, suffer severely in the sequel for the transitory pleasure derived from it. The habit induces constitutional debility, loss of appetite and memory, early decrepitude, and shortness of life. The person is characterized by a listless, dull manner, and an unconquerable aversion to any exertion of mind or body. While not under the influence of the spell, his despondency amounts to an indescribable horror of mind. All his motions are embarrassed by an universal tremor of the limbs: he becomes paralytic, perhaps apoplectic, and he expires in a fit. The habitual use of opium induces nearly the same train of diseases as an inveterate habit of drinking ardent spirit. An overdose of this

potent drug may occasion *risus Sardonicus*, alienation of the mind, madness, convulsions, apoplexy, and death. Its effects are not confined to its internal exhibition: Galen mentions, that an opium plaster laid on a gladiator's head by a stratagem of his enemy, speedily deprived him of life; and physicians witness the effects of external opiates continually.

Dr. Trotter says, "It is well known that many of our fair countrywomen carry *laudanum* about them, and take it freely when under low spirits." Let such contemplate and tremble at the eventual horrors of this practice.

The plant called wild hemp (*Cannabis Indica*), in Egypt named *Assis* or *Haschish*, is manufactured into a substance called *Bangue* or *Bang*, which is much used throughout Egypt, Persia, Arabia, and Hindoostan as a powerful and peculiar inebriant. For this purpose, a liquor is prepared from its juice, or its dried leaves are made use of. The common people among the Arabs pound the leaves, make a little ball of them, and swallow it.* In Hindoostan the plant is grown for no other use than for the purpose of intoxication. It produces tranquillity of mind and a singular kind of exhilaration, during which the person laughs involuntarily, speaks incoherently, and sings and dances without staggering or giddiness. Like opium, it stimulates courage and excites sensual propensities. During sleep it promotes agreeable dreams.

It is singular that the common hemp plant and even the flax plant seem, in their effects on the animal economy, to be related to the wild hemp, called *bangue*. Lindenstolpe says, that the effluvia of the fresh herb hemp weaken the eyes and affect the head. And Ray says, that the water in which the herb has been steeped is a violent and sudden poison. Common flax is suspected to give a like poisonous impregnation to the water in which it is long macerated, insomuch that the steeping of both flax and hemp in spring or running waters,

* Pococke's Travels in Egypt.

or in ponds where cattle drink, is prohibited by law. Such water is also poisonous to fish.

In most of the South Sea Islands they prepare an intoxicating liquor from a pernicious root called in the Friendly Islands *kava*, but at Otaheite and the Sandwich Islands *ava:* the liquor itself is called by the same name. The manner of preparing it is not only disgusting in the extreme, but unnecessarily so; for more obvious and cleanly methods could with the greatest ease be made use of, and are actually practised elsewhere. Mr. Anderson gives the following account of it: "The *kava* is a species of pepper, which they cultivate and esteem a valuable article: it is commonly planted about their houses. The root is the only part used at the Friendly Islands, which being dug up, is given to the servants that attend, who, breaking it in pieces, scrape the dirt off with a shell; and then each begins and chews his portion, which he spits into a piece of plantain leaf. The person who is to prepare the liquor collects all these mouthfuls, and puts them into a large wooden dish, adding as much water as will make it of a proper strength. It is then well mixed up with the hands, and some loose stuff, of which mats are made, is thrown upon the surface, which intercepts the fibrous part, and is wrung hard, to get as much liquid out from it as possible. The quantity which is put into each cup is commonly about a quarter of a pint. The immediate effect of this beverage is not perceptible on these people, who use it so frequently; but on some of ours who ventured to try it, though so hastily prepared, it had the same power as spirits have in intoxicating them; or rather it produced that kind of stupefaction which is the consequence of using opium, or other substances of that kind. Though these islanders have this liquor always fresh prepared, it is nevertheless so disagreeable, that the greatest part of them cannot swallow it without making wry faces and shuddering."* Beside intoxicating and stupefying, this baneful root commits dreadful ravages on its unfortunate

* Cook's Last Voyage, i. 318.

votaries, who, well aware of its effects, choose to purchase a transitory gratification at the cost of health, and even life. " Some of us (says Captain Cook) who had been at these islands before, were surprised to find many people who, when we saw them last were remarkable for their corpulency, now almost reduced to skeletons; and upon enquiring into the cause of this alteration, it was universally allowed to be the use of the *ava*. The skins of these people were rough, dry, and covered with scales, which they say every now and then fall off, and their skin is, as it were, renewed."

In the islands of Java and Savu the natives make wine, which they call *tuac*, from the fan-palm. On cutting the buds which are to produce flowers, a juice trickles out: this is collected, and partly converted into sugar, and partly into wine, by fermentation, after which it intoxicates powerfully. It is also the common drink of the natives before it has undergone fermentation.

The date fruit is produced on a kind of palm-tree, which grows in India, Arabia, and Africa, in the south of Spain, and the southern islands of the Mediterranean. The tree lives two or three hundred years. The juice of the fruit, by fermentation, affords a wine, and this again an ardent spirit. This wine of palm is of great antiquity. Herodotus says, that the principal article of commerce in Babylonia was their palm-wine, which they carried in casks (Clio). He says, that the Egyptians also knew it, and used it in embalming for washing the intestines (Euterpe).

In some parts of India a wine is prepared from the liquor contained in cocoa nuts; this they call *tari:* by distillation of it they obtain a spirit called *calou*, which is dangerous to Europeans, as it induces dysentery. In Persia, an alcoholic liquor is distilled from the fermented juice of peaches. The same is done in South America: but by far the greatest part of their ardent spirit is procured from a saccharine juice which flows from the sugar maple tree on wounding it: this is fermented and distilled.

Strahlenberg*, in his description of Russia, gives the following account:—The Tartars and Calmucks give the name of *arki* to a vinous spirit which they obtain by distillation of mares' or cows' milk. They first put the milk into untanned skins sewed together; they let it sour and thicken. They then agitate it until a thick cream appears on the surface. This they remove, and dry in the sun, and give it as food to their guests. But they drink the sour milk; they call it kumyss: or they draw from it a vinous spirit, by distillation. Gmelin adds, that the whole process is exceedingly disgusting; and that the spirit, although very strong, exhales a disagreeable odour. The Tartars affirm that, after intoxication with this liquor, they experience no pain of the head. Twenty-one pounds of milk afford six ounces of strong spirit.

The possibility of obtaining ardent spirit from milk has been disputed by many chemists; but the experiments of Oseretskowsky of Petersburg have proved that it is possible. The result of his experiments is, that milk does not undergo the vinous fermentation, if the butter and cheese are taken from it; either must remain: and that whey, although it contains the whole of the sugar of milk, does not enter into the vinous fermentation, even although yest be added. The researches of Professor Spielmann and Dr. Clarke have confirmed the statements of other travellers on this subject.

All the American Indians are much addicted to intoxication, and they have various methods of inducing a state, in their estimation, so desirable. They have contrived to make wine from palm-juice; and a kind of ale from Indian corn, or the *manioc* root: these they drink with great freedom. The European settlers in North America introduced the modes of intoxication practised in their own country, and called in the powerful assistance of their spirituous liquors in the work of exterminating the unfortunate aboriginal tribes; and, truth to say, they found no difficulty in bringing them into high

* Quoted by Le Normand, i. 410.

favour. It is reported by a French author that one of these poor savages being asked his opinion of brandy, to the use of which he was so much devoted, answered, in the florid style of his country, "it is made of tongues and hearts; for when I have drank it I fear nothing, and talk like an angel." *

The Rhododendron Chrysanthum, or yellow-flowered Rhododendron, a native of Siberia, infused in hot water, like tea, is used amongst the Siberians as an enlivening beverage. In large quantities it produces intoxication, sometimes of so outrageous a kind as to amount to actual delirium. A century since it was employed by the natives as a cure for rheumatism, and subsequent trials elsewhere have proved that it is not without advantage.

Tea, especially green tea, is another of the vegetable intoxicating substances: it is made use of by all civilized nations for its enlivening qualities. Taken strong, and in great quantity, it produces exhilaration, an indescribable feeling of lightness of body, as if in one's step he scarcely touched the ground; along with a perception of increased magnitude, apparently, of all objects. Swallowed in very great excess, it produces horror of mind, an intolerable apprehension of sudden death, and fits of asphyxia or suspended animation.† There can be no doubt that, in abundant doses, it would prove a powerful and sudden narcotic poison. The royal poet of China, the late emperor Kien-long, composed an ode eulogising tea. He first describes the mode of drawing tea, which, when divested of his peculiar and methodical phraseology, is just the same as our own. "On a slow fire (he says) set a tripod, whose colour and texture show its long use. Fill it with clear snow water. Boil it as long as would be sufficient to turn fish white and crayfish red. Throw it upon the delicate leaves of choice tea. Let it remain as long as the vapour rises in a cloud, and leaves only a thin mist floating on the surface. At your ease drink this precious liquor, which

* Quoted by Murphy, transl. of Tacitus.
† Dublin Hospital Reports, vol. i. p. 219.

will chase away the five causes of sorrow. We can taste and feel, but not describe, the state of repose produced by a liquor thus prepared." Tea indeed is a beverage, the use of which is quite consistent with the temperance of the Chinese character. They distil a spirit from millet and from rice: but they make only moderate use of it. They also make beer from rice, in which they sometimes infuse the seeds of thorn-apple (*Datura Stramonium*), to add to its narcotic power. It is made so strong, that when contained in close vessels, and buried, as is their custom to do, it will keep sound for a number of years.

The seeds of the thorn-apple are also used as an inebriant by the Turks: they sometimes substitute them in the place of opium.

Coffee is a well known, and, when rightly prepared*, an exceedingly powerful exhilarant. It is used by almost all nations. The Turks heighten its effects by the admixture of a little opium, the bitterness of which it in a good measure disguises.

In Britain, a method of producing intoxication has been discovered which partakes more of the exhilarating and overpowering character than of the ferocious or maniacal. Its subsequent effects, as far as known, unlike those of other inebriants, are not detrimental. The agent which produces these effects is a gas; it is a protoxide of nitrogen: it is made to act on the animal economy, not by swallowing, but by breathing it. If an oiled silk bag, quite free from smell, and containing this gas, be furnished with a tube to hold in the mouth, and the whole so arranged that a person can draw the gas into his lungs, and breathe it backward and forward a few times, it will produce extraordinary sensations, generally of a highly pleasurable kind, accompanied by increased vividness of ideas, propensity to muscular exertion, involuntary laughter, and the greatest exhilaration, without the subsequent languor and depression that follow ebriety. In peculiar constitutions we sometimes find the only effect,

* See Dublin Philosophical Journal, vol. ii. p. 149. for the mode.

in the first instance, to be a sensation like the approach of fainting. I have seen it produce effects in all respects apparently similar to apoplexy, but it was momentary, and did no injury.

The vapour of alcohol copiously inhaled into the lungs produces the same effects as if it had been swallowed. This kind of ebriety is common to coopers, porters, and other workmen employed in cellars and distilleries. It is transitory, and disappears when the person is brought into the open air.*

The smoke of tobacco, merely drawn into the mouth, without being inhaled into the lungs, acts powerfully on the nervous system, and produces the effects of a stupefying narcotic: hence its use amongst the lower orders. The chewing of tobacco has the same influence; and if the saliva be swallowed, its effects are powerful and dangerous. The powder of tobacco, called snuff, drawn into the nostrils, produces on those unaccustomed to its use immediate but momentary intoxication, along with much sickness. This baneful plant is supposed to have been introduced into England by the fleet of Sir Francis Drake, in 1586.

Along with the intoxicating substances unfortunately now too well known to all the world, these described, and a few others of uncertain efficacy, constitute almost the total number. I shall not pursue the subject further; but proceed to some historical sketches of the introduction of a few of them into society.

Well known as intoxicating liquors appear to have been in the early history of mankind, very little of the details of what was known has descended to us through the writings of antiquity. From this it might, perhaps, be inferred that their use was much more common even than we suppose. Facts with which every one is acquainted will seldom formally find their way into written records, unless such as are composed for the express purpose of conveying elementary instruction, a task never undertaken in the infancy of communities. Hence we find wines, &c. alluded to by ancient historians and poets;

* Dr. Trotter's Essay.

but we know almost nothing of their characters or differences, or the processes by which they were obtained, further than the general outline inferred from our present methods, and few scattered records.

When we consider how simple and obvious the process is of obtaining wine from the grape, we are led to conclude that the invention of it must be nearly coeval with the existence of that fruit. The delightful sweetness of its juice, and its succulency, must have suggested the desire, as well as the facility, of separating the juice from the fruit, and using it as an agreeable, harmless drink. The principle of fermentation is present in the grape: the juice, if kept a few hours, will spontaneously ferment; and the singular appearance of the effervescence, resembling boiling in the cold, would be a sufficient stimulus to curiosity to insure a completion of the process. Meanwhile, the taste would become vinous; and the effects, when swallowed, would be so singular and so enlivening, that frequent recourse would be had to a process which afforded a liquor of such powerful and pleasing influence over the mind. It is, therefore, very probable that wine was discovered nearly six thousand years since, very shortly after the creation of the world. But from Scripture we know to a certainty, that "Noah began to be an husbandman, and he planted a vineyard. And he drank of the wine, and was drunken." From this we may infer that Noah, after the flood (year B.C. 2348), merely practised an art previously well understood in the antediluvian world: he must actually have understood the nature of wine and of its previous fermentation; for without this, grape juice could not intoxicate. He even made wine on the large scale, for he planted a vineyard. And not only does it appear that he understood the cultivation of grapes in a vineyard, but that such knowledge constituted a part of the province of the husbandman. The mode of narration in Scripture and every other consideration tend to prove that the making of wine had been an art long practised before the flood, and not invented by Noah, as has been often supposed. If otherwise, the

extensive cultivation of grapes, such as a vineyard implies, would scarcely have been undertaken for the mere sake of the fruit. We have, therefore, certain evidence that wine has been known upwards of four thousand years, and presumptive evidence that it was known nearly two thousand years earlier.

What the name of wine might have been, in the primitive language of mankind, there are now no means of determining; but it is very probable, that it was much the same word as is used to express it by Moses in Gen. ix. 21. viz. יין from ינה to press out. From the similarity of the name of wine in most known languages, it seems probable that all nations derived their knowledge of that beverage from the antediluvian world through Noah; and that the discovery was not made (as I may express myself) a second time, in any future age, or by any other nation. From יין we have *οινος* in the Greek, *vinum* in Latin, *vino* in Italian and Spanish, *vin* in the French, *wein* in the Gothic, *gwin* in the Welsh, *uin* in the Cymbric, uuin in the old German, *viin* in the Danish, *wiin* in the Dutch, ƿin in the Saxon, and *wine* in the English.

The invention of an intoxicating liquor from corn has been attributed to the Egyptian deities Osiris and Isis, who, while on earth, were great benefactors to an industrious and intelligent people. However backward the modern Egyptians may be in agriculture, Osiris collected all the information on the subject within his reach, and taught it to his people, who then practised it with effect: and in these labours he was effectually assisted by his wife and sister Isis, the Ceres of the Romans. The opinion entertained by those of our own times, who have attempted to trace the history of fermented liquors, is that the Egyptians, not having grapes, possessed no wine; and that, as their climate required the aid of such a stimulant, Osiris, one of their princes, invented the art of making a wine from corn.

There are certainly passages in the ancient writers which seem to countenance this opinion, if not positively

to support it: but there has been some misconception, and even misquotation. The subject is several times alluded to by Diodorus Siculus. In the first book he says, that wherever the vine was not found, Osiris taught the people to make a drink from barley, not much inferior to wine in point of fragrance and efficacy. Again, he says, in the same book, a drink which they call *zythum* is made by the Egyptians from barley, not much exceeded by wine in smell and taste. In the fourth book, the amount of two passages is, that Bacchus (who is the same as Osiris) having discovered the management of the grape, and the properties of wine, taught mankind how to make a drink from barley, called by some zythum, not much inferior to wine in flavour and fragrance; when their climate and country were such as not to produce grapes.

In these passages it is nowhere said that the Egyptians had no grapes, and that on this account they were obliged to use barley-wine. Herodotus, indeed, gives some colour to the opinion, when his statements are connected with those of Diodorus. Herodotus says, the Egyptians use wine made from barley, for their country does not produce the vine.* To this statement we may oppose another made by Diodorus in his third book: he says Bacchus (i.e. Osiris) is reported to have taught the Egyptians the management and use of the vine, as also of wine, apples, and other fruit. Now his tuition would have been to very little purpose if they had no vines. In short, the supposition that there was any thing in the soil, climate, or condition of Egypt unfriendly to the growth of grapes cannot hold. Dr. Pococke, during his travels through Egypt, met with numbers of vineyards, from the grapes of some of which the Christians made very good wine. Many of these vineyards were on the banks of the Nile, which still, as it ever did, overflows its boundaries and inundates the country. Other travellers report that grapes are grown

* Οινῳ δ' εκ κριθεων πεποιημενῳ διαχρεωνται, ου γαρ σφι εισι εν τῃ χωρῃ αμπελοι.—HEROD. *Euterpe.*

throughout all the adjoining countries, and on the shores of the Levant. Testimony is also deducible from antiquity. Moses says nothing direct of vines in Egypt: but the persons whom he sent to "spy out the land of Canaan," not very far from Egypt, returned and brought from the brook Eschol a cluster of grapes which required two men to carry it.* This might well be: clusters of grapes are recorded in modern times weighing from twenty to forty pounds, — no inconsiderable load for a twenty days' journey. When the Israelites murmured against Moses and Aaron, in the desert of Zin, they said, "and wherefore have ye made us come up out of Egypt, to bring us into this evil place? It is no place of seed, or of figs, or of *vines*, or of pomegranates: neither is there any water to drink."† Here is actual allusion made to the vines of Egypt. Is it to be supposed that the most important of all fruits would be found in the most luxuriant profusion in Syria, and be neglected in a next neighbouring country, which produced the pyramids, and at one time contained 20,000 cities, and the soil and climate of which are proved to have been well calculated for their cultivation? If there be any truth in the opinion that Osiris was son of Ham, son of Noah, who so well understood vineyards and wine, can we suppose that a prince, so anxious for the instruction of his subjects in arts, would have omitted to introduce an art considered of such importance to a community? This reasoning applies with the more force, as it is not stated at what particular time Egypt was without vines.

I am aware that there is a passage of Plutarch which seems to afford testimony of a very opposite nature to the facts and inferences here brought forward: and even to assign a powerful reason, not only for the neglect of vines, but even for their extermination. Plutarch says that, until the days of their king Psammetichus, who died B. C. 617., the Egyptians did not drink wine, believing it to be the blood of those giants that had

* Numbers, xiii.   † Ibid. xx. 5.

been killed in their wars with the gods. The vine (as they supposed) grew from the ground impregnated with the blood of the giants: and hence they did not offer libations of wine to their gods, believing it to be abhorrent to them.

From this account, one might be at once inclined to infer, that the religious hatred of the ancient Egyptians to wine was the source of the invention of barley-wine as a succedaneum for an article which they believed necessary in so moist a climate: for according to Herodotus (Euterpe), no nation in the world paid more attention to health and dietetics. But as Plutarch, as far as I can learn, is the only ancient author who affirms that the Egyptians entertained these notions, although so many others have described their manners and customs, the statement comes to us comparatively unsupported. And were the case such as he represents it, the grape would have fallen a victim to their superstitious zeal, would have been exterminated, and could not have been alluded to by the Israelites as one of the enviable productions of Egypt, as it is stated by the inspired writer. And as Diodorus, who lived almost two centuries before Plutarch, tells us that Bacchus is reported to have taught the Egyptians the use of wine, it is obvious that he would have modified, contradicted, or observed upon the report, had he ever heard of the facts stated by Plutarch. Nor would he have introduced the subject as matter of praise to any person who had taught the use of a fruit that was abhorrent to the notions of the most superstitious people in the world.

There is other testimony which seems decisive against the statement of Plutarch. The royal psalmist, who lived twelve centuries before Plutarch, and whose information must have been so much more correct, in recounting the visitations of the Egyptians, which took place four centuries before, says, " he smote their *vines* also, and their fig-trees, and brake the trees of their coasts." Here, then, not only a punishment, but a severe one, for disobedience to the will of the Almighty,

was inflicted through the intervention of a fruit, which, it is therefore clear, must have been considered by the Egyptians as an object of their greatest solicitude instead of abhorrence.

There are also other statements which are yet to be noticed. We have it on the authority of Hellanicus, that *wine was first known at Plinthion, a town of Egypt:* "hence the Egyptians are thought to derive their immoderate love and use of this liquor, which they thought so necessary to human bodies, that they invented a sort of wine made from barley, for the poorer sort, who wanted money to purchase that which was pressed from grapes."* This, indeed, seems to be the truth: it is more consistent with reason and history, sacred and profane; and it is quite clear that wine could not have been first known at an Egyptian town, if the Egyptians had no vines.

As some have it, the counsellor and friend of Osiris was Mizraim, grandson of Noah. Some say that Osiris was himself Mizraim, the descendant of the just man. Probably this wise and powerful prince took the invention of an intoxicating liquor from corn, either directly or indirectly, from the illustrious person whose transgression against temperance is perpetuated in the sacred record.

If Mizraim and Osiris be the same person, it would follow that Osiris reigned as the first monarch of Egypt 2188 years before Christ: the empire continued during 1663 years. Beer would, therefore, now be an invention of about 4000 years, it being understood to mean unhopped beer or barley wine: hopped beer is a modern improvement.

It is a singular circumstance that the word *beer* seems to be of Hebrew origin, as well as the name of the other fermented liquor, *wine*, and that the invention of both should be thus traceable to the family of Noah. If we read the word בר *corn* without the vowel point, merely supplying a short enunciating vowel, it will sound like *bre* in *sabre*, or *ber*. The Hebrew language modified

* Potter, Antiq. Gr.

tself into the Phœnician, and that again into the Saxon. We accordingly find the Saxon word bepe, *barley*, to have a singular resemblance to its parent בר. The colouring given by the ancient Saxon to the languages of Europe is perceptible in many words: hence we have the English *beer*, the French *bière*, and the Italian *birra*. Some derive the word *beer* from the Latin verb *bibere*, to drink, — a sufficiently remote analogy. If the derivation be from the Latin at all, I think it more probable that it is from *bevere*, the word made use of in place of *bibere* towards the end of the sixth century, when the Latin ceased to be a living language. *Bevere* was no doubt pronounced at that time as it would have been by the earlier Romans, *be-we-re:* it was afterwards contracted into *bere.* But the Saxon bepe has been retained in English up to the present time, for there is a kind of barley called *bere* or bigge. The English word *beer* was, a few centuries since, spelt *bere:* and beer has at all times been made from barley. We may therefore incline to believe, that the etymology of the word not only proves the remote antiquity of the beverage, but traces the invention to the family of Noah, provided that the grandson of the patriarch was really monarch of Egypt.

The Latin word *cerevisia* (beer or ale) is derived in the same way, the name of Ceres, goddess of corn, being applied to corn itself.

Admitting, then, that the invention of barley-wine originated in Egypt, not because they had no vines, but because a stimulating liquor, cheaper than grape wine, was required for the use of the common people, we can trace the use of it extending throughout Europe. Dion Cassius says, that "the Pannonians who inhabit the banks of the Danube have neither oil nor wine, except a very little, and that little very bad: they eat barley and millet, and from these two kinds of grain make a drink." * We learn from Ammianus, that a similar liquor, called *sabaia*, was prepared from barley or wheat

* Lib. 49.

in Illyricum. Tacitus declares, that the ancient Germans were much addicted to drunkenness, and that amongst them "it was no disgrace to continue drinking night and day:"—"they prepared a beverage from barley or wheat, which they made into a liquor somewhat resembling wine. Those who live near the banks of the river purchase wine." * Pliny exclaims, "the whole world is addicted to drunkenness: the perverted ingenuity of man has given even to water the power of intoxicating, where wine is not procurable. Western nations intoxicate themselves by means of moistened corn." †—"A drink made in this way is called *zythum* in Egypt, *celia* and *cerea* in Spain, and *cerevisia* in Gaul and the other provinces." ‡ It would appear that the barley wine, as made in some countries, was rather an indifferent beverage: that of the Germans was "humor ex hordeo *corruptus*." The *sabaia* of the Illyrians is called by Ammianus "*liquor paupertinus*," a poor or weak liquor. Xenophon, however, describes the οἶνος κρίθινος, or barley wine, of Armenia, as a very strong liquor, if not mixed with water; and very grateful to those accustomed to its use. §

It is only in this indirect way that we can learn any thing concerning the quality of the corn wines of antiquity, because we know nothing of the mode of preparation. Were we acquainted with the process, the case would be otherwise; and the chief fact of which we are ignorant is, whether or not any *ferment* was made use of. Without yest, the slight fermentation, which takes place spontaneously in corn liquors, would afford a poor, vapid, acidulous drink, with very little exhilarating power; and to the taste of us moderns it would prove not a little disgusting. Yest was certainly known

* De Morib Germ. § 22.

† Est et occidentis populis sua ebrietas *fruge madida*. Plin l xiv c 22 I conceive *fruge madida* alludes to the malting process which the corn was made to undergo, the first stage of which is moistening or steeping it in water If so, the passage is valuable, as it supplies a part of the process, upon which all other authors are silent The translation of these two words given by Dr Henry, — "corn and water," — seems not to be borne out by *madida*, and to lead to a false sense.

‡ Plin l xxiii. c. 25.

§ Anabasis (Hutchinson), 209.

to the ancients: Pliny says, "the frothy head of all these liquors is used by ladies for beautifying the skin of their faces *;" but he does not say that it was used in brewing. At Pelusium, situate on the Pelusian mouth of the Nile, they made a sweet and a bitter drink from barley: the former was called *carmi,* the latter was the *zythum.* Professor Beckmann says, that, according to Columella, this bitter taste was communicated to it by the bitter lupine; but, on reference to Columella, I find no such passage. I have already assigned a reason for believing that the corn was malted; and there is this stronger reason for supposing it, — that raw corn would afford scarcely any ardent spirit, and the liquor would be weak and vapid. From Athenæus we learn, that the barley, whatever state it was in, was bruised; so that, on the whole, it appears probable that zythum was much like our beer, and prepared in the same manner. The barley was first malted, then ground; next an infusion was made with water; to this, perhaps, yest (then certainly known) was added, after the proper bitter had been communicated: the fermentation then proceeded.

A drink of much the same nature is still common in Egypt. Dr. Pococke says, "the most vulgar people make a sort of beer of barley without being malted; and they put something in it to make it intoxicate. They make it ferment: it is thick and sour, and will not keep longer than three or four days." †

We possess some more certain information with regard to ancient grape wines. The juice of the grape naturally contains both the ferment and the fermentable matter; hence the qualities of wine must have been in all ages pretty much the same, and there could have been but little variety in the process.

Gibbon observes, that in the age of Homer the vine grew wild in Sicily and the neighbouring shores, but no wine was made from it. One thousand years after, Italy could boast that of fourscore most generous wines more than two thirds were produced by her own soil.

* Lib. 22. in fine. † Description of the East, i. 182.

Amongst the Romans wine was made by trampling the grapes so as to bruise them well. Part of the juice ran out spontaneously, and was kept apart for making a better sort of wine, called πρώτοπον, or *vinum primarium*. Another part was obtained by the press and strainer: it afforded a worse wine, called δευτέριον. The fermentation was then allowed to proceed; and, when finished, the wine was cleared with the yolks of pigeons' eggs, and then stored in earthen or leathern vessels, well stopped up. These were often hung in the smoke of a chimney, at some distance above the fire, in order to mellow. Columella says, that this practice imparts to wines a premature age:—"*Vina celerius vetustescunt quæ fumi quodam tenore præcoquem maturitatem trahunt.*" *

The first use for which wine was employed by the Romans was in religious ceremonies; and for ever after, even at their feasts, the custom was retained of pouring out a libation to the gods, before they drank any themselves. The Greeks did the same, and employed it as a libation to the dead. Its use was for a long time very limited. Roman women were not allowed to drink it, unless at sacrifices. To smell of it was a great disgrace; and a woman convicted of drinking to intoxication was visited with no less a punishment than death. It was considered a national stigma on the Grecian ladies that, according to the custom of their country, they drank wine, even while unmarried. Men under the age of thirty were not allowed wine, unless on religious occasions. In time it began to be used more freely: vineyards were cultivated in such abundance, that, in order to protect the interests of agriculture, and to check the growth of intemperance, an edict was issued by Domitian, ordering the destruction of half the vineyards, and prohibiting the further planting of vines without licence from the emperors. This law was abrogated by Probus, who ascended the throne A.D. 276.

At Roman feasts the wine was contained in earthen-

* Lib i 6.

ware vases or glass bottles, with a label indicating its age and quality; for they set the greatest value on the oldest wines. Sometimes the wine was perfumed; and often it was cooled with snow. It was almost always mixed with water, being seldom drank by itself: the guests did not mix it; but for this purpose boys of great beauty were in attendance, who measured it into cups as required. The mixing of water with wine, at all feasts, was enforced amongst the Greeks. As the Scythians and Thracians mixed no water, and were much addicted to drunkenness, if a Lacedæmonian did the same he was stigmatised as a Scythian toper. The wine at Roman entertainments was served at the second course along with fruits. A piece of etiquette,—to dispense with which would have been a manifestation of pride, and to comply with which would in the present day be considered a strange piece of politeness,—was to taste a cup of wine, and then hand the same cup to some other person. So Martial's keen epigram on a person who had a bad breath, or a sore mouth:—

> "Quod nulli calicem tuum propinas
> Humane facis, Herme, non superbe" L. ii. 15.

> "That when you've drunk you offer none your glass,
> Should, not for pride, but for good breeding, pass."

The Romans drank healths, either to each other or to an absent friend; and the quantity drank was in an exact proportion to the number of letters in the person's name,—not to the degree of friendship.

But the most extraordinary of their convivial customs was the following. A skeleton was sometimes introduced at feasts, or the representation of one, in imitation of the Egyptians; upon which the master of the feast, looking at it, used to say, Drink and be merry, for thus thou shalt be after death.* Strange indeed must have been the temper of mind that could be excited to mirth by such a spectacle.

* Ἐς τοῦτον ὁρέων πῖνέ τε καὶ τέρπευ· ἔσεαι γὰρ ἀποθανὼν τοιοῦτος.
Herod. b. ii. 78.

The Romans and Greeks had a great variety of wines, and they seem to have been not a little devoted to their use, as appears by the frequent mention of them by their poets. Amongst the early Greeks drunkenness from wine was quite fashionable; and for the invention of the means of intoxication they paid divine honours to Bacchus. Saturn had the honour of the invention amongst the Romans. Falernian, Chian, Opimian, Massic, Surrentine, and a variety of others, were in high estimation. The *vinum Sabinum* was, perhaps, the worst in use:—

> "Propinas modo conditum Sabinum
> Quisquam plumbea vina vult in auro" MARTIAL.

> "Why give vile Sabine, — that not even old, —
> Worthless as lead, though quaff'd from cups of gold"

Some of their wines were flavoured with a kind of pitch, or with aromatic herbs. Many of the Roman wines were of an extraordinary age, and were proportionately valued:—

> "Vinaque perpetuis ævo certantia fastis." STATIUS.

Horace speaks of wine "Marsi memorem duelli," that is, nearly 70 years old. It was sometimes drank at 100 years of age. And the Opimian wine, which had been made in the time of the consul Opimius, was 200 years old. Pliny probably expressed his own opinion only when he dispraised wine of more than 20 years old. In order to preserve their wines to these ages, the Romans concentrated the *must* or grape juice, of which they were made, by evaporation, either spontaneous in the air, or over a fire, and so much so as to render them thick and syrupy. The Lacedæmonians had an extraordinary custom of boiling away a fifth part of the wine. They then kept it by for four years, when it was fit for drinking. Were our modern wines thus treated, they would have few votaries.

The process of evaporation to a syrupy consistence is by no means necessary to their being preserved, as was desired amongst the Romans: wines not treated that way

have been known to keep equally long. Newman informs us, that "the tartish German wines keep the longest of any: some of them have been kept for two or three hundred years: and in Strasburg there is a cask four hundred years old, and many above seventy; the wine being occasionally racked off into smaller and smaller casks, that the vessel may be continually full. These very old wines are preserved rather for curiosity than use, as they not only grow too strong for drinking, but at last quite disagreeable." * Some years since, in an old well in London, were found some bottles of wine, which from various circumstances, especially the glass being in a state of decomposition, and the shape of the bottles, were considered of great antiquity. On account of a quantity of burnt wood which surrounded them, it was thought that they had lain there since the great fire of London in 1666. One of these bottles contained excellent Malaga: the others contained what appeared to have been port; but the spirit had changed into vinegar, and the vegetable matter was in a state of putrefaction." † During the excavation of the ancient city of Herculaneum, which was buried by an eruption of Vesuvius more than seventeen hundred years ago, an earthen vase containing wine was found in a cellar: it was solid, and resembled a mass of porous, dark violet-coloured glass. It is probable that this mass had been an evaporated wine.

Many of the wines described by the ancient writers seem to have been rather the stock from which wine was to be made, than the wine itself. They were often so thick as to require solution in hot water, and filtration, before they were fit for drinking, as appears by the statements of Pliny and Aristotle. From the circumstance of their being in this soft-solid form, it appears they could not have been much fermented. *Must*, unless as liquid as water, will not ferment; and if wine, after evaporation, leaves any residuum sweet and agreeable to the taste, it is proof that any degree of fermentation to

* Newman's Chemistry, p 445 † Brande's Journal, i 136.

which it had been subjected must have been trivial. Besides, it is an opinion maintained by respectable authorities, that boiling down any sweet vegetable juice has a tendency to lessen its susceptibility of fermentation. Newman says, " it is observable that when sweet juices are boiled down to a thick consistence, they not only do not ferment in that state, but are not easily brought into fermentation, when diluted with as much water as they had lost in the evaporation, or even with the very individual water that had exhaled from them. Thus sundry sweet liquors are preserved for a length of time by boiling." (p. 441.) From these considerations, it is probable that the qualities for which the Romans and Greeks valued their wines were very different from those sought after in the present day; that they contained much saccharine matter, and little alcohol.

The supposition that they contained but little alcohol corresponds with the facility with which they froze in temperatures which stronger wines would have sustained. Xenophon mentions, that after the celebrated retreat of the 10,000 Greeks, they encountered such a frost and fall of snow in the plains of Bithynia (now a part of Anatolia), that the wine froze in the vessels in use at their meal.* Ovid, while in banishment at Tomos, in Lower Mœsia (now Bulgaria, in European Turkey,) writes of the neighbouring climate that they took their wine in lumps: " nec hausta meri, sed data *frusta bibunt.*" † And Virgil ‡, speaking of the people on the northern shores of the Black sea, says,—

> " But where Mæotis Scythia's§ waste divides,
> And turbid Ister rolls his yellow tides,—
> There crystal chains at once whole pools confine,
> And hatchets cleave the congelated wine."

Some have affected to disbelieve the accounts given by the ancients of the freezing of their wines; but well might this have happened when there are authenticated facts on record of the freezing of the strong wines of

* Anabasis, Z'. † Tristia, I 3. ‡ Georgics III.
§ Virgil means *Sarmatia's.*

modern times, and even of spirit of wine, if not pure. It appears, however, that a kind of analysis of the wine takes places in the process, the watery part separating from the spirituous portion,—the former freezing, and the latter sometimes remaining liquid in the centre. Paracelsus had observed this, but expressed it in the enigmatical language of his day: he speaks of striking the essence of wine to the centre by means of cold. Boyle froze French and Rhenish wines into ice. He relates as follows:—"A physician of my acquaintance having purchased some Malaga sack at Moscow, which was drawn from a frozen hogshead of the same liquor, it proved much better and stronger than was expected; but the remaining part of the ice, being thawed, was little more than phlegm. The doctor also observed the like to happen in some other liquors: he did not, however, find the spirituous part always retired to the centre of the vessel, but that it lay sometimes interspersed among the ice." Mr. Boyle also instances that certain wines brought to Moscow are so frozen on their arrival, that the casks are staved, and the wine cleaved with hatchets. He further adduces the case of a barrel of strong beer, left by some sailors on shore in Greenland. On their return, next year, it was found hard frozen; "but running a heated spit into the middle of the ice, there issued out a turbid liquor that was exceedingly strong and spirituous, whilst the frozen part was almost insipid." *

In Ellis's voyage for the discovery of a north-west passage (1746 and 7), it is stated that at Hudson's Bay, lat. 57° 30′, some of the casks of small beer were frozen, and the casks burst. In the heart of the ice the spirituous parts remained fluid: this liquor was strong, but the ice, when melted, tasted quite vapid. † But we shall not doubt that wine freezes, when we read the following from the same account:—"If we touch iron or any other smooth solid surface in the winter, our fingers are frozen fast to it; if in drinking a dram of brandy out

* Shaw's Boyle, i. 610.

† Ellis, p. 180.

of a glass, one's tongue or lips touch it, in pulling them away the skin is left upon it. An odd instance of this kind happened to one of our people, who was carrying a bottle of spirits from the house to his tent; for not having a cork to stop the bottle, he made use of his finger, which was soon frozen fast, by which accident he lost a part of it to render a cure practicable." He further adds, "strong brandy, and even spirits of wine, will freeze; but the latter not into a solid mass, but to the consistence of oil, when the weather is between temperate and freezing. All the liquors under *proof* freeze to a state perfectly solid, and burst the vessels that contain them, whether of wood, tin, or even copper."

Hollinshed mentions the freezing of ale and wine amongst other prodigies. "In the daies of king James I. (who ascended the throne 1306), sundrie strange and monstrous things chanced in Scotland. At Perth there was a sow that brought foorth a litter of pigs with heads like unto dogs. A cow also brought foorth a calfe having a head like a colt. In the harvest before the king's death, a blasing star was seen with long streaming beams. And in the winter following the frost was so vehement, that ale and wine were sold by the pound weight, and then melted against the fire." (V. p. 428.) "Frozen ale was sold by weight in 1109 in Scotland, the frost being intense." (p. 304.)

From all these instances it therefore appears incontestable that wines may be frozen, and that there is nothing fabulous in the statements of the writers of antiquity.

We have next to trace the progress of the different vinous liquors which have been made use of in the British isles in ancient times. Previously to the conquest of Britain by the Romans (B. C. 55.), agriculture was almost entirely unknown in the island. The Romans, well versed in this important branch of knowledge, taught the British the arts of peace as well as of war; and, during the time that they maintained possession of the island, so far advanced were the inhabitants in civilis-

ation, that they exported corn and cattle in abundance, as well as metals, and pearls of great beauty. Before the introduction of agriculture into Britain, says Dr. Henry *, *mead*, that is, honey diluted with water, and fermented, was probably the only strong liquor known to its inhabitants, as it was to many other nations in the same circumstances. This continued to be a favourite beverage amongst the ancient Britons, and their posterity, long after they had become acquainted with other liquors. The mead-maker was the eleventh person in dignity in the courts of the ancient princes of Wales, and took place of the physician. The following ancient law of that principality shows how much this liquor was esteemed by the British princes:—"There are three things in the court which must be communicated to the king before they are made known to any other person: first, every sentence of the judge; second, every new song; and, third, every cask of mead. This was, perhaps, the liquor which is called by Ossian the joy and strength of the shells, with which his heroes were so much delighted.

Mead was a favourite and an ancient drink in Ireland. It is mentioned in the seventh century, and was called by the Irish *miodh* and *mil-fion*, that is, honey-wine. It is mentioned in the life of St. Berach, who flourished in the seventh century, and in the annals of Ulster under the year 1107.† That it was a common drink in Ireland would be probable, had we no stronger evidence, from the great abundance of honey in the country: it was so abundant, indeed, as to be an article of export. From a pamphlet printed in London, 1649, we learn that a ship was freighted at Waterford, and captured on her passage: she was laden with 70 tons of kelp, 13 packs of skins, 8 barrels of tallow, 6 packs of wool, 5 sacks of linen yarn, and 9 hogsheads of honey. But Cambrensis says, "We had at this time plenty of Poitou wine, which we took in exchange for poultry; and which

* Hist. England, ii. 362 † Ware (by Harris), ii. 182.

Lombarde, in the seventeenth century, declares was our chief wealth."*

After the general introduction of agriculture into Britain by the Romans, ale or beer became the common drink of all the British nations, as it had long been of all the Celtic people on the Continent. The method by which the ancient Britons and other Celtic nations made their ale is thus described by Isidorus and Orosius (begining of fifth century): "the grain is steeped in water, and made to germinate: it is then dried and ground; after which it is infused in a certain quantity of water, which, being fermented, becomes a pleasant, warming, strengthening, and intoxicating liquor." This ale was most commonly made of barley, but sometimes of wheat, oats, and millet.† Its taste was essentially different from modern ale, as there were no hops made use of, but in place of them various disagreeable bitters. The Danes, while in Ireland, are said to have used *heath* for brewing their ale.

Ale takes its name from the Danish word *oela*. The Britons gave it the old name *kwrw* or *cwrw*, for which we have, by corruption, in Dioscorides, *curmi*.‡ He says (B. C. 30.), the Britons and Iberians (Hibernians), instead of wine, use curmi, a liquor made of barley. A Norman poet banters this liquor with more wit than truth in Latin verses, of which the following is a translation, substituting in one line a Latin word for the very plain English used by the translator:—

"Of this strange drink, so like the Stygian lake
Men call it *ale*, I know not what to make
They drink it thick, *et mingunt* wondrous thin:
What store of dregs must needs remain within!"

The Irish have no name for this drink but *learn*, which signifies liquor in general; but they understand by it *ale*.§ They drank ale on all occasions, at ordinary entertainments, and even at funerals. For the custom of the ancient Irish was to convert a funeral into a

* Ledwich's Antiq. of Ireland.
† Henry, Hist. of Eng ii. 362
‡ Camden, 302.
§ Ware, ii. 182.

festival; as, indeed, is pretty much the case with the lower orders to this day. They are said to have taken this custom from the Germans; and, although an unbecoming one, it is not more so than the usage of the polished Romans, who acted comedies at funerals. The *Adelphi* of Terence, a play of no very moral tendency, was performed at the funeral of the Roman general Paulus Æmilius, B. C. 168. Mr. Hardiman, in his "Ancient Deeds," p. 80., gives us a translation of an Irish award made in 1592, which mentions that Loghlin Roe is entitled to "a great cow, which was killed for the funeral of John M'Murrogh O'Slattery, together with all the wheat and *liquor* provided for the same." The killing of the cow is explained by the following curious canon concerning the rights of a dead body, taken from an ancient Irish synod, in these words: "every dead body has in its own right a cow, and a horse, and a garment, and the furniture of his bed: nor shall any of these be paid in satisfaction of his debts, because they are, as it were, peculiar to his body."

The manner of serving the ale at entertainments amongst the ancient Irish is thus described by Sir James Ware. When the Irish were at their ordinary entertainments, they sat down in a ring, on rushes or beds of grass, instead of benches or couches. When they were placed, three-legged wooden tables were set before them, covered with victuals, after the manner of the ancient Gauls; such as bread baked on a gridiron or under the ashes, milk-meats, flesh and fish both broiled and boiled: the waiters in the mean time serving drink about in cups made of wood or horn, and sometimes of brass.

It is very probable, if not certain, that wine was not known to the Britons previously to the Roman conquest. The Britons were a simple and barbarous people. It is not likely that a nation living in turf-built huts, amidst woods and bogs, whose painted bodies were covered by the skin of some animal, which was their only garment, had as yet obtained from foreign countries such an

article of luxury as wine, or could prepare it from a fruit not a native of their soil. Indeed, they held little intercourse with any nation. Herodotus, who wrote four centuries and a half before the Christian era, knew little more of the islands called Cassiterides, one of which is Britain, than that it exported tin. The Phœnicians were the only people that maintained any commercial intercourse with the island; or that, in fact, exactly knew its situation on the globe: and their knowledge they carefully kept to themselves. The grape was not, at this period, known as a possible production of Britain: nor was it grown there for many centuries after. Tacitus asserts, that "the soil abundantly produces all fruits except the olive, the grape, and some others, which are indigenous to a warm climate." *

There is still stronger testimony than this. Boadicea, queen of the *Iceni* (now the country about Norfolk), having been treated with the utmost barbarity by the Roman conquerors, determined (A.D. 61.) to avenge her wrongs. Preparing for battle, she harangued her army. In an eloquent appeal to their feelings she said,—comparing the simple habits of her country with those of the Romans,—"to us every herb and root are food; every juice is our oil; and *water is our wine*— πᾶν δε ὕδωρ οἶνος." † This seems a distinct declaration that they had no wine.

On the accession of Probus to the imperial purple (A. D. 278.), that illustrious emperor, having achieved the conquest of Gaul, revoked the edict of Domitian, and privileged the provinces to plant vines, and make wine. Britain was included in the licence. The Romans had been emigrating into Britain for nearly three centuries previously to this period; and they brought with them the arts and manufactures of their own country. Some time previous to this, wine had been abundantly imported into Britain: but wine was actually made there about A. D. 280. Bede says, (A. D.

* In Vitâ Agricolæ, § 12.

† Dion Cassius, lib. lxii. 1. In the meagre report given of this famous speech by Tacitus the above passage does not occur.

731.) "vineas etiam quibusdam in locis germinant." And Holinshed brings forward the following proofs, "that wine might haue growne in this iland heretofore: first the charter that Probus the emperour gaue equallie to vs, the Galles, and Spaniards, is one sufficient testimonie. And that it did grow here, beside the testimonie of Beda, the old notes of tithes for wine that yet remaine in the accompts of some parsons and vicars in Kent and elsewhere; besides the records of sundrie sutes commensed in diverse ecclesiasticall courts, both in Kent, Surrie, &c.; also the inclosed parcels almost in every abbeie yet called vineyardes, may be a notable witnesse. The ile of Elie also was in the first times of the Normans called *le ile des vignes*."* Winchester is supposed to have taken its name from its vines. Bishop Hamson sent to Edward II. "a present of his drinks, and withal both wine and grapes of his own growth in his vineyard at Halling." Captain Nicholas Toke, of Godington, in Kent, says Philipot, "hath so industriously and elegantly cultivated and improved our English vines, that the wine pressed and extracted out of these grapes seems not only to parallel but almost to outrival that of France." Domesday Book, the materials of which were collected in 1086, mentions at Rageney, in Essex, one park and six arpennies of vineyard, which, if it takes, will yield twenty modii of wine. The practice was, if the grapes ripened well to make wine; if not, they made verjuice, which, before lemons were introduced, was substituted for that fruit. The neglect of English wine is attributed by Twine, in part, to the fondness for French wine which came on us in the reign of Henry III. In the time of Edward III., when England had the command of so great a part of France, there must have been plenty of French wines in England. The principal cause, no doubt, of the neglect of English wines was, that the French were better, and could be had cheap from our French provinces. Few of our religious foundations were formerly

* Chronicles, [illegible]186.

without vineyards. Dr. Ralph Bathurst, president of Trinity College, Oxford, made as good claret in 1685 as could be wished for. At Arundel castle in Sussex, says Mr. Millar, a noble vineyard belonging to the Duke of Norfolk annually yields considerable quantities of wine; at this time, 1763, says he, there are in his grace's cellar above sixty pipes of excellent Burgundy, much better than quantities annually imported.*

As to malt liquors, the British Isles have been always remarkable for the excellence of them. "Our ancestors," observes Mr. Pinkerton, "prided themselves in the variety and richness of their ales; and old writers enumerate many sorts, as Cock, Stepney, Stitchback, Hall, Derby †, Northdown, Nottingham, Sandbach, Betony, Scurvygrass, Sage-ale, College-ale, China-ale, Butler's-ale, &c.: nor even at present do we refuse praise to the various qualities of our Burton, Dorchester, Taunton, Scottish, and other ales. But the most peculiar malt beverage is *porter*, which ought to be solely composed of brown or high dried malt, hops, *liquorice*, and *sugar*, but is sometimes debased by other ingredients. That of London is particularly famous, and is an article of exportation, being esteemed a luxury on the banks of the Delaware and the Ganges. *Punch* was another national liquor, composed of spirits, water, acids, and sugar: but its use is now on the decline, though the late Dr. Cullen esteemed it a salutary potion in a moist and variable climate."‡

Frequently the character of some of these malt liquors was derived from very unwarrantable sources; and often was contributed to as much by the druggist as by the maltster or hop merchant. Well might a certain French traveller observe, that the English commonly drink at their meals a *sort of medical ptisan*, which they call *small beer*: for, in fact, very often it was really so in nature.

* Millar's Gardener's Dict art. Vine.

† This ale was in high repute, even in the days of Camden, two centuries and a half ago. See Britannia, 302. edit. 1586.

‡ Pinkerton's Geography, i. 62.

Ale is a beverage of great antiquity in Great Britain and Ireland. But the ale of these periods, and until the sixteenth century, contained no hops. Dr. Lannigan, speaking of St. Finnian of Clonard, one of the two sees of Meath, who died A.D. 552, says, "Finnian was distinguished, not only for his extraordinary learning, and knowledge of the Scriptures, but likewise for his great sanctity, and austere mode of living. His usual food was bread and herbs; his drink water. On festival days, he used to indulge himself with a little fish, and a cup of *beer* or whey." * Ale is mentioned in the laws of Ina king of Wessex, who ascended the throne about the year 689. It was one of the articles of a royal banquet provided for Edward the Confessor, about the middle of the eleventh century. About this period of ignorance and brutality in England, gluttony and riotous amusements occupied the place of arts and sciences. William of Malmsbury declares, that "the English in the reign of Henry II. (1154 to 1189) were universally addicted to drunkenness, continuing over their cups day and night, keeping open house, and spending the income of their estates in riotous feasts, where eating and drinking were carried to excess, without any elegance." Even the monasteries fell into these luxurious habits: but they might do so without censure; for the monks were, in these times, the most influential persons in the state. In 1540, when the monasteries were suppressed, there was no less a number of them than 645 in England and Wales. The monasteries were always remarkable for having the best wine and ale, the latter of which they brewed for themselves, with remarkable skill and care. "The best wine," says Holinshed, "was called *theologicum*, because it was had from the cleargie and religious men, vnto whose houses manie of the laitie would often send for bottels filled with the same, being sure that they would neither drinke nor be served of the worst, or such as was anie waies mingled

* Ecclesiastical Hist. c. x § 5. Dr. Lannigan was a man of deep learning and research: he has not given the original word; but, no doubt, he had good grounds for what he wrote.

or brued by the vintner: naie, the merchant would have thought that his soule should have gone streightwaie to the divell, if he should haue served them with other than the best."* The monks and prior of St. Swithin once prostrated themselves in the mire before Henry II., complaining with tears and doleful lamentations that their abbot had curtailed three dishes from their table. "How many has he left you?" said the king. "Ten only," replied the monks. "I myself," exclaimed his majesty, "have never more than three, and I enjoin you to the same." In the reign of Edward IV. (1470), an installation feast was given by George Nevil, Archbishop of York, at which the guests had the liberal allowance of 300 tons of ale, and 100 tons of wine: that is, in all, above one hundred thousand quarts of liquor. But this was certainly not too much, when we consider that there were much above 7000 animals, of different kinds, served up to table, on the occasion of creating this "right reverend father in God." The king's own brother, the Duke of Clarence, was, by a last effort of fraternal indulgence, permitted to terminate his earthly career by drowning in a butt of his favourite beverage, Malmsey wine.

Unfortunately, the facility of procuring intoxicating liquors in these times, at a low rate, kept pace with the propensity of the people to consume them: and the same wholesome restrictions were not imposed on their use as have been of late years, when civilisation has made greater progress. About the year 1050, the best ale could be bought for eight-pence the imperial gallon of the present day. This was spiced ale; it was double the price of common ale: and mead was double the price of spiced ale. Ale was spiced for sake of flavour, as well as for preservation: cloves are said to prevent the souring of this liquor.† In 1199, King John set a rate on the price of wines: Rochelle wine was to be sold for twenty shillings the ton, or four-pence for a single gallon; wine of Anjou twenty-four shillings the tun, or

* Holinshed, i. 282.

† B. Castelli Lex. art. *Cervisia.*

sixpence the gallon; no other French wine to be above twenty-five shillings the tun. Twelve honest men, in every town, should superintend this assize. "But this ordinance did not last long, for the merchants could not bear it; and so they fell to, and sold white wine for eight-pence the gallon, and red, or claret, for sixpence." * In the reign of Henry III., who ascended the throne 1216, a dolium or thirty-six gallons of the best wine could be bought for forty shillings, and sometimes for twenty. And in 1251, during the same reign, an assize of bread and ale was struck, which settled the price of ale as follows:—"a brewer may sell two gallons of ale for a penny in cities, and three or four gallons for the same price in the country." The penny of that time was worth about three-pence of the currency in the time of Hume, from whom this last fact is taken. In the reign of Richard II. (1387), wine was so abundant in England, that it was sold for thirteen shillings and four-pence the tun, and twenty shillings the best; that is, for the best, less than one penny per gallon.† Anno 10 Edw. IV. (1471), a parliament was held at Dublin, in which it was enacted that the following shall be the *maximum* prices, in Ireland, of the different articles named:—A gallon of the best beer three halfpence; a gallon of Rochelle wine, sixpence, or under; a gallon of Gascoine wine, eight-pence, or under; a gallon of Spanish wine, ten-pence, or under.‡ Holinshed calculates the first cost of ten score gallons of beer in his day, about the year 1550, at twenty shillings, that is, not quite $1\frac{1}{4}d.$ per gallon.

Some centuries since, ale and wine were as certainly a part of a breakfast, in England, as tea and coffee are at present, and even for ladies. The Earl of Northumberland, in the reign of Henry VIII., lived in the following manner:—"On flesh days through the year, breakfast for my lord and lady was a loaf of bread, two manchets, a quart of beer, a quart of wine, half a chine

* Holinshed, ii. 278 † Holinshed.
‡ Taken from the MS. statute roll, 10 Edw IV. c. 5. Rolls' office Dublin.

of mutton, or a chine of beef, boiled. On meagre days, a loaf of bread, two manchets, a quart of beer, a quart of wine, a dish of butter, a piece of salt fish, or a dish of buttered eggs. During lent, a loaf of bread, two manchets, a quart of beer, a quart of wine, two pieces of salt fish, six baconed herrings, four white herrings, or a dish of sproits." *

After the introduction of the hop from the Netherlands, which took place very shortly after the beginning of the same reign, the quality of all the malt liquors in England was much improved, and they became more extensively used. Shortly after, during the Dutch war, the English, according to Baker, "learned to be drunkards, and brought the vice so far to overspread the kingdom, that laws were fain to be enacted for repressing it." Hume relates that the Earl of Leicester gave Queen Elizabeth an entertainment, in Kenilworth castle, which was extraordinary for expense and magnificence. Among other particulars, we are told that 365 hogsheads of beer were drank at it. Now in this quantity there are 23,000 gallons; and if there were 23,000 persons present, which is not possible, it would still be an allowance of a gallon to each; — a tolerable exhibition before a queen. Many such entertainments were accepted by this queen, who professed to restrain luxury and extravagance, and issued sumptuary edicts; but she did not ennoble precept by example.

In the history of fermented liquors, the countries to the north of Europe hold a conspicuous place. If the ancient Germans were notorious for their addiction to intoxicating liquors, it appears that their descendants, the early inhabitants of northern Europe, retained an hereditary love for beverages of the same kind. So necessary did they appear to the comfort and well-being of that people, that they flattered themselves with the belief that these pleasures were not to cease even with life, but would constitute a part of the rewards of the

* Household Book of the Earl of Northumberland, quoted by Lord Kames.

virtuous in a future state. Ragner Lodbrog, the last king of Scandinavia, who ascended the throne A. D. 750, was a brave and powerful prince, and withal a poet. In a descent upon England he was taken prisoner, and put to a cruel death. Serpents were thrown into his dungeon, and by the stings of these venomous reptiles his life was terminated. In the midst of his last agonies, he amused himself with his favourite pursuit, poetry, and composed a very extraordinary ode, in which are mixed up the notions of a future state entertained by his nation, from which the following is extracted:— "We fought with swords: I am still full of joy when I think of the banquet that is preparing for me in the palace of the gods. Soon—soon, in the splendid abode of Odin, we shall drink beer out of the skulls of our enemies."—"But it is time to cease. Odin hath sent his goddesses to conduct me to his palace. I am going to be placed on the highest seat, there to quaff goblets of beer with the gods. I will die laughing." *

About seventy years before the birth of Christ, the renowned Odin reigned over Scandinavia,—a warrior, an orator, and a poet. A Scythian by birth, he overran the north of Europe, and, finally, became a monarch. After his death, which was by his own hand, divine honours were paid to him. In his dying moments, he told his people that he would receive, in a place of bliss, the souls of all those who lived virtuously, and died gloriously in the field of battle. The name of the place where they were to be received was the palace of *Valhall.* In the twentieth fable of the *Edda,* which, as every one knows, is a compilation from the Gothic Mythology, collected previously to the year 1241, from ancient traditions, we find the following singular colloquy. "But," says Gangler, "if every man who has been slain in battle since the beginning of the world repairs to the palace of Odin, what food does that god assign to so vast a multitude?" Har answered him, "the cook Andrimner dresses the wild boar incessantly in his

* See M. Mallet's Edda.

pot: the heroes are fed with the lard or fat of this animal, which exceeds every thing in the world; as to Odin himself, wine is to him instead of every aliment; the victorious Odin takes no other nourishment to himself than what arises from the unremitted quaffing of wine." Gangler proceeds and demands "And what is the beverage of the heroes which they have in as great abundance as their food? Do they only drink water?" Har says to him "You put a very foolish question. Can you imagine that the universal Father would invite kings, and chiefs, and great lords, and give them nothing but water? In Valhall there is a she goat which feeds on the leaves of the tree lerada; from her paps flows hydromel or mead in such great quantities that it every day completely fills a pitcher large enough to inebriate all heroes."

The only value in this absurd fable is the historical light which, probably, it throws on the drinks of the ancient northern Europeans. Here we have wine and mead mentioned in conjunction with the era of Odin. For although the Edda was collected at so late a period, we must recollect that the matter contained in it is older than the Christian era. And we may observe, that the mead mentioned is not merely hydromel (honey and water), as stated in Bishop Percy's translation of the passage, but was a real fermented wine of honey, capable of producing intoxication, or what has by some been called vinous hydromel.

On this passage, the French translator, Mons. Mallet, observes, "wine was very scarce in those times, and almost unknown. Beer was, perhaps, a liquor too vulgar for heroes. The Edda, therefore, makes them drink hydromel or mead, a beverage in great esteem among all the German nations. The ancient Franks made great use of it. Gregory of Tours, speaking of a certain lord who generally drank it, adds 'ut mos barbarorum habet.'"

Mead has been used as universally as anciently; it has found its way even into the interior of Africa. Mr.

Park says that the Mandingoes, a race of pagan negroes, drink it to excess. A kind of beer is also made by the African negroes from the *holcus spicatus*, much in the same way as ours is from barley.

The last question to be investigated in the history of intoxicating liquors is, at what time alcohol was first separated from vinous liquors by distillation, — a very important era also in the history of man. In this enquiry we only arrive at a near approximation to the time of the discovery, the precise period, as well as all knowledge of the discoverer, being now perhaps irrecoverably lost. I shall take M. le Normand as my guide.

Pliny, who lived in the first century of the Christian era, has left an excellent treatise on vines and wine, but is silent on the subject of its spirit, which assuredly he would not have been, had he possessed so valuable a secret.

Galen, who lived a century after Pliny, speaks of distillation only as a means of extracting the aroma of plants and flowers; but speaks nothing of the distillation of wine.

Rhazes, Albucassis, and Avicenna, three celebrated Arabian physicians and philosophers, who lived about the tenth and eleventh centuries, mention the distillation of roses, a process in their country much in esteem as affording a perfume greatly valued by their kings and nobles: but they do not allude to the distillation of wine.

Arnold de Villanova, a physician of the thirteenth century, formally declares that the ancients knew nothing of spirit of wine. He informs us that this extraordinary liquor had been then lately discovered; and that it was believed to be the universal panacea which had been so long sought after.

Raymond Lully, who was born in 1236, and died in 1315, and was the contemporary and pupil of Arnold, affirms that this admirable product from wine, which one can consider, says he, in no other way than as an

emanation of the divinity, was concealed from the ancients because the human race was then too young: so precious a discovery, he adds, was reserved for the renovation of its decrepit old age. He says that the discovery of this divine liquid induces him to believe that the end of the world is not far distant.

Lully details two processes for concentrating spirit of wine, or in other words for abstracting water from it. The first is distilling it from lime; the second from calcined tartar, that is, carbonate of potash. In the first case, he anticipated the proposal of Gay Lussac; and in the second, that of Lowitz. Bergman says that the rectification from quicklime was the discovery of Basil Valentine.

Bergman, in his History of Chemistry, declares that Thaddeus of Florence, who was born in 1270, Arnold de Villanova, and Raymond Lully are the first three persons who mention spirit of wine. The last gave the name of *alcohol* to the strongest spirit.

It is, therefore, pretty certain that the discovery of spirit of wine was made about the middle of the twelfth century, and that the discovery was made by the alchemists. These persons treasured up the process, as a profound and important secret, for a length of time; and it was not for ages after that it became generally known, or was practised as an art.

Michael Savonarole who wrote a treatise in Latin on the art of making spirit of wine, an edition of which was published in 1560, more than a century after his death, informs us that it was only used as a medicine. The physicians of these days attributed to it the important property of prolonging life; and on this account it was called *aqua vitæ*, water of life. In this work he launches out into a panegyric on the virtues of this wonderful panacea:—"est et aqua vitæ dicta, quoniam in vitæ prorogationem quàm maximè conferre sentiat. Sum etenim memor ejus verbi quod sæpe hilari corde gravissimus ille vir et in orbe sua ætate clarissimus medicus, Antonius Delascarparia, exclamando pronuntiabat,

qui, dum octogesimum annum duceret, dictabat: *o aqua vitæ, per te jam mihi vita annos duo et viginti prorogata fuit.*" The wonder certainly is, that this venerable gentleman, who was so much addicted to brandy, as appears by his own confession, should have attained his eightieth year.

It is pretty certain, that for a length of time after the discovery of spirit of wine, it was treasured up as a valuable secret in the possession of a few; that it was prepared only in the laboratories of chemists, who in these days were always of the medical profession; and that the early possessors of the secret did not deal in the spirit as an article of commerce. M. le Normand shows reason to believe that its distillation on the large scale was inconsiderable until about the end of the seventeenth century, and that even then the manufacture was of little importance, when compared with what it became at the beginning of the eighteenth century.

At what period the art of distillation was introduced into Britain is not certainly known: it is commonly believed to have taken place during the reign of Henry II. It would appear that in Ireland the practice of obtaining a spirit from malt was better understood, even at the earliest period of the invention, than elsewhere. In the Irish language the spirit was called *Uisge-beatha* or *Usquebah.* Moryson, who was secretary to Lord Mountjoy, during the rebellion in Ireland of the Earl of Tyrone, wrote a history of Ireland, including the period between 1599 and 1603, which in many respects is one of the grossest libels that ever defiled the page of history; in this he nevertheless gives the following account: — "At Dublin, and in some other cities (of Ireland), they have taverns, wherein Spanish and French wines are sold; but more commonly the merchants sell them by pints and quarts in their own cellars. The Irish aqua vitæ, vulgarly called usquebagh, is held the best in the world of that kind, which is made also in England, but nothing so good as that which is brought out of Ireland. And the usquebagh is preferred before our aqua vitæ, because

the mingling of raisins, fennel-seed, and other things, mitigating the heat, and making the taste pleasant, makes it less inflame, and yet refresh the weak stomach with moderate heat and good relish. These drinks the English-Irish drink largely, and in many families (especially at feasts) both men and women use excess therein:" — "neither have they any beer made of malt and hops, nor yet any ale; no, not the chief lords, except it be very rarely." — "But when they come to any market-town to sell a car or horse, they never return home until they have drunk the price in Spanish wine (which they call the King of Spain's daughter), or in Irish Usquebagh, and until they have outslept two or three days' drunkenness." The latter passages prove how little this writer was disposed to praise any thing Irish, had praise been undeserved.

Sir James Ware supposes that ardent spirit was distilled in Ireland earlier than in England. He says, "the English aqua vitæ, it is thought, is the invention of more modern times. Yet we find the virtues of usquebagh and a receipt for making it, both simple and compound, in the red book of Ossory, compiled nearly two hundred years ago; and another receipt for making a liquor, then called *nectar*, made of a mixture of honey and wine, to which are added ginger, pepper, cinnamon, and other ingredients." Dr. Ledwich observes, that the early French poets speak of this nectar with rapture, as being most delicious. The Irish distilled spirits from malt in 1590, and imitated foreign *liqueurs*, by adding aromatic seeds and spices, as was practised in France, so early, according to le Grand, as 1313. The Irish *bulcaan*, Rutty tells us, was made from black oats. *Buile*, madness, and *ceann*, the head, intimate the effects of this fiery spirit.

Having now sketched an account of the introduction and use of intoxicating liquors, as far as the few annals preserved have furnished materials for it, as a proper sequel we may notice the consequences of indulgence

in these insidious poisons. Fortunate, indeed, were it for mankind, if the history could truly terminate with an account of their introduction, and if there were nothing to be added to complete the subject. But a dismal picture remains to be exhibited of the effects of excessive indulgence. It is the more to be lamented that the power which those stimuli possess over the intellectual economy should be turned to such bad account, when, under proper restrictions, they might have been made conducive to real benefits. From them, rightly administered, the afflicted in mind or body might receive comfort, the desponding might be inspired with hope, and the melancholy elevated into joy. But the limits of moderation are easily surpassed. He who experiences these advantages does not always rest satisfied with their reasonable enjoyment: the cup of bliss continues to be quaffed, but the infused poison throws round him its magic spell. His senses no longer convey true impressions. Innocent hilarity gives place to mischievous mirth: good humour and benevolence are converted into causeless quarrel and vindictive rage: the faculties of the man are only recognisable by their perversion: and fortunate for him is it if the progress of crime is arrested by the death-like profundity of apoplectic sleep. How unenviable are his awaking moments!—memory confused with obscure recollections of insult received and outrage committed; the body exhausted and oppressed; and the mind harassed with the terrors of a remorse-stricken conscience. Amidst the repetition of these practices, the springs of health are dried up; an appalling train of diseases derange the functions of the body; the withered frame wastes down into sepulchral tenuity; the grave closes on the victim, and he is remembered only with the contemptuous pity of mankind.

There is something so singular in the progress of the habitual drunkard, the vicissitudes which he experiences are so extraordinary, and his fate sometimes (if we may credit recorded cases) so frightful and out of the ordinary

course of nature, that it may not be useless or uninteresting to enter a little on the subject, with the view of forewarning those, who are as yet undebased, of the punishment which may overtake them in their career, should they fall into this temptation. The methodical delusions of the drunkard, while in a state of transitory derangement, for such we must suppose intoxication to be, have often been the cause of adventures that might be considered ludicrous but for the humiliation which human nature is forced to acknowledge in their contemplation. Dr. Trotter and others relate some curious anecdotes of this kind. We read of a drunken man whipping a post in the street until he was tired, which he mistook for a person that would not move out of his way; and of an old gentleman of eighty years of age, who, when in his cups, became so amorous as to take a lamp-post for a lady, and address it with all the language of passion and flattery. An officer, much accustomed to hard drinking, after getting intoxicated at the mess-table, fell asleep: he awoke suddenly, and addressed one of his brother officers in a peremptory tone, saying, that, as it was an affair of honour, now was the best time for settling it. He insisted on taking the ground immediately: and no small remonstrance was required to convince him that he had been dreaming. A drunken company of young men, while in a tavern, fancied they were in a ship at sea during a tempest. To lighten the vessel and avoid shipwreck, they threw all the furniture of the house out of the window, as they thought, into the sea. When taken before a magistrate, they persisted that it was done to avoid imminent danger, and made promises in case they ever came to land. We are told of a person, who found himself insurmountably obstructed on his journey by the shadow of a sign-post. And of another, who attempted to light his candle in the moon, which he saw shining through a hole in the wall.

These are trivialities, only calculated to make the agent in them ridiculous and contemptible, and they are productive of little injury to society. But let us exa-

mine the criminal calendar, and investigate the extent of social outrage produced by addiction to intoxicating liquors. We shall find the most atrocious murderers, the most adventurous highway robbers, the most subtle and dangerous sharpers, and, in fine, the most flagitious offenders against the laws of God and man, urged on in their fatal career by that deluding poison which falsifies perception, and distorts all objects of sense. And where the rights of others have not been violated so as to call for the sanguinary interposition of the law, punishment in this world is yet sure to fall on the devoted drunkard. The tremulous hand, the tottering step, the drowsy eye, imbecile manner, emaciated frame, and squalid aspect are sure precursors of the destruction which is about to happen. Then come liver disease, jaundice, and dropsy. The tragedy quickly runs through its brief acts; the last scene arrives, and the catastrophe is completed.

But fortunate is this gradual termination of his offences and sufferings, when compared with the frightful visitation which has sometimes been affirmed to overtake the miserable victim in the midst of his career, without affording him one moment to review the errors of his past life, or to resolve on repentance and amendment. There are instances on record in which, if true, the laws of nature seem to have been suspended, and new powers have been called into operation, in order to bring about one of the most awful visitations that can be well conceived. It is attested from various sources of authority, and there are published records of the fact, that the body of the habitual drunkard has spontaneously taken fire, without the contact of any burning substance, and has been suddenly consumed to ashes. A number of instances have been collected by M. Lair*, from which the following are extracted: —

In 1692, a woman, who for three years had used spirituous liquors to such an excess that she would take no other nourishment, having sat down one evening to sleep,

* Journal de Physique, iii. Phil. Mag. vi. 132.

was consumed in the night-time, so that next morning no part of her was found but the skull and the extreme joints of the fingers. All the rest of her body was reduced to ashes.

Mary Clues, aged fifty, was much addicted to intoxication. Her propensity to this was such, that for about a year scarcely a day passed in which she did not drink at least half a pint of rum, or aniseed water. Her health gradually declined; she was attacked with jaundice, and was confined to her bed. She still continued her old habit of drinking. One morning she fell on the floor; and her weakness having prevented her getting up, she remained so till some one entered and put her to bed. The following night she wished to be left alone. A woman, on quitting her, had put coal on the fire, and placed a light on a chair at the head of the bed. At five in the morning a smoke was seen issuing through the window; and the door being broken open, some flames which were in the room were soon extinguished. Between the bed and the chimney were found the remains of the unfortunate Clues. One leg and a thigh were still entire; but there remained nothing of the skin, the muscles, or the viscera. The bones of the cranium, the breast, the spine, and the upper extremities were entirely calcined. The furniture had sustained little injury. The side of the bed next the chimney had suffered most: the wood of it was slightly burnt; but the feathers, clothes, and covering were safe. Nothing except the body exhibited any strong traces of fire.

A similar case is the following:—a woman about fifty years of age, who indulged to excess in spirituous liquors, and got drunk every day, was found entirely burnt, and reduced to ashes. Some of the osseous parts only were left; but the furniture had suffered very little damage.

A woman at Paris, who had been accustomed for three years to drink brandy to such a degree that she used no other liquor, was one day found entirely reduced to ashes, except the skull and extremities of the fingers.

We find, in the Philosophical Transactions, a well-attested case of human combustion. Grace Pitt, aged about 60, had a habit of coming down from her bed-room, half-dressed, to smoke a pipe. One night, she came down as usual. Her daughter, who slept with her, did not perceive she was absent till next morning, when she went down to the kitchen, found her mother stretched out on the right side, with her head near the grate, having the appearance of a log of wood consumed by fire, without an apparent flame. The fetid odour and smoke which exhaled from the body almost suffocated some of the neighbours, who hastened to the girl's assistance. The trunk was in some measure incinerated, and resembled a heap of coals covered with white ashes. The head, the arms, the legs, and the thighs had also participated in the burning. This woman had drunk a large quantity of spirituous liquor. There was no fire in the grate, and the candle had burned entirely out in the candlestick, which was close to her. Besides, there were found near the consumed body the clothes of a child and a paper screen, which had sustained no injury. The dress of this woman consisted of a cotton gown.

Le Cat mentions the following case. The Sieur Millet had a wife who got intoxicated every day. This woman was found consumed, at the distance of a foot and a half from the hearth, in her kitchen. A part of the head only, with a portion of the lower extremities, and a few of the vertebræ, had escaped combustion. A foot and a half of the flooring under the body had been consumed; but a kneading trough and a powdering tub, which were very near the body, had sustained no injury. The husband declared, that about eight in the evening he had retired to rest with his wife, who, not being able to sleep, had gone into the kitchen; that, having fallen asleep, he was awoken about two o'clock by an infectious odour; and that having run into the kitchen, he found the remains of his wife in the state above described. It was very unfortunate for Millet that he had a handsome servant-maid; for neither his probity nor his innocence

would have been able to save him from the suspicion of having got rid of his wife by a concerted plot, but that by an appeal to an enlightened court, which discovered the cause of the combustion, he came off victorious.

Le Cat relates another instance, which occurred 1749. Madame de Boiseon, 80 years of age, exceedingly meagre, who had drunk nothing but spirits for several years, was sitting in her elbow-chair before the fire, while her waiting-maid went out of the room for a few minutes. On her return, seeing her mistress on fire, she immediately gave an alarm, and some people having come to her assistance, one of them endeavoured to extinguish the flames with his hand, but they adhered to it, as if it had been dipped in brandy. Water was thrown on the lady in abundance, yet the fire appeared more violent, and was not extinguished till the whole flesh had been consumed. Her skeleton, exceedingly black, remained entire in the chair, which was only a little scorched.

These instances will suffice, although others are recorded. M. Lair is of opinion, that by the constant use of spirituous liquors, the bodies were rendered highly combustible; but that, in all cases, some burning body must primarily have been applied. M. le Cat, on the other hand, maintains that the burning was spontaneous, and without the application of external fire.

M. Julia de Fontenelle has lately read a paper to the Academy of Sciences at Paris on spontaneous human combustions; and from fifteen cases related, he has drawn a number of conclusions, of which the following are the chief:—Generally, those who have suffered were habitual and excessive indulgers in alcoholic liquors. Old women are most subject to spontaneous combustion. The combustion is almost always general, but sometimes it is partial: the feet, hands, and top of the head are the only parts that have been preserved. Although a very large quantity of wood is necessary for burning a corpse, this kind of burning occurs without inflaming the most combustible substances. The presence of air is shown not to be necessary; and it is found that water, instead of

extinguishing the fire, only gives it more activity. When the flame has disappeared, the combustion continues within the body.

M. Julia de Fontenelle conceives all former explanations of these phenomena to be inapplicable, and proposes one which seems very little less so: he says that the combustion depends on an advanced and putrid degeneration of the system, which suddenly produces very combustible substances, these inflaming spontaneously on account of being in oppositely electrical states. The putrefaction of vegetables sometimes develops so much heat as to cause inflammation.

Whichever of these opinions is true, it appears that the body was brought to such a state as not only readily to catch fire, but rapidly to burn into ashes; neither of which catastrophes would have happened, unless some very unusual agency were in operation. In any case, these are good lessons against intemperance. Perhaps (says M. Lair) the frightful details of so horrid an evil as that of combustion will reclaim drunkards from their practices. Plutarch relates that, at Sparta, children were deterred from drunkenness by exhibiting to them the spectacle of intoxicated slaves, who filled the minds of these young spectators with so much contempt, that they avoided drunkenness for ever. What if they had been told the history of these combustions?

CHAP. II.

ON THE CULTIVATION OF BARLEY INTENDED FOR MALTING.

We now enter on the proper subjects of this volume The foundation of the whole process of the brewer and distiller is the art of malting. In order to produce malt of the best quality, we must pay great attention to the barley from which it is obtained: and this attention

ought to be paid, not only to the very sowing of the seed, but even to the preparation of the soil which is intended to receive it. This being the case, it will be necessary to enter a little on the cultivation of this grain, and to point out the particulars to be attended to, so as to furnish the maltster with a grain that will not defeat the efforts of his skill.

Fermented liquors may be produced from any of the different kinds of grain, as barley, bere, oats, wheat, rye, rice, and maize. Malt liquors, in the present day, are prepared from the seeds of *Hordeum distichon*, or barley, one of our most valuable kinds of grain, originally a native of Tartary. There are many species of this annual; the most common are the two-rowed barley, or Hordeum distichon; and the four-rowed or Hordeum vulgare, commonly called *bere*. The qualities of both are nearly the same: bere is obviously a coarser and less nutritious grain than barley. A Winchester bushel of very good barley, on an average, weighs fifty pounds; and of bere but forty-eight. Bere is more rapid in passing through all the stages of vegetation; and it thrives sufficiently well in a poor soil.

In the northern parts of the kingdom, barley is sown in April; but in the southern parts a month sooner. The seed chosen should be free from blackness; its colour should be pale but brilliant; and, above all, it should be full bodied. In dry weather, it is said to be of great use to steep the seed for a day in water, before it is sown: we thus obtain a better and more equal crop. The seed, if intended for malt, should not have been grown on the soil where it is intended to be sown; but ought to be taken from some totally different soil, in a remote situation. Indeed, in any case, the seed should be changed constantly; for, if not, the crop will be coarse.

The quantity of seed to be sown on every acre depends in a great measure on the nature of the soil. It is the opinion of many, that poor soils require more seed,

and rich soils less. Some conceive that by sowing much seed, the crop will grow more evenly, and will be equally good throughout, a circumstance of the greatest consequence to the maltster. There is, however, a chance, in this case, of having weak straw, and of the corn lodging. But the safest opinion is, that the point is as yet undecided. Perhaps it may be near the truth to say that, on an average, from two to four bushels of seed per acre should be used. The resulting crop is, of course, very variable; for average land and seasons, the crop may be rated at somewhat under thirty bushels per acre. Fourteen pounds of barley afford twelve of meal.

After the seed is sown, and even after it has grown a few weeks, the action of a heavy roller will be required to pack the soil round the grain, and to protect the roots, when grown, from being parched. On the quality of the seed much of the success of the processes, to which the barley is afterwards to be subjected, depends; and, unfortunately, it is one of the most delicate kinds of grain in the growth, and most liable to receive irreparable injury. In order to prevent the ravages of insects, soot is often mixed with the water in which the seed has been steeped, previously to its being sown. The *smut* is the chief disease of barley; and for this, there is no remedy known. During the growth of the barley, the ground should be carefully freed from weeds; for the seeds of such will often give a very ill taste to malt worts.

The land that produces the best barley is a sharp, light, pulverulent, and dry soil. A sandy loam succeeds well. Soils, which being composed chiefly of argillaceous earth, are peculiarly retentive of water, are called cold or wet soils: such are very improper for the growth of barley; and more especially if the subsoil possess a similar quality, such as clayey gravel. The land is prepared by loosening and breaking down the clods, by means of light ploughing, cross ploughing, and harrowing, or better by the scarifier. The seed should

then be immediately sown, while the surface is still recent. The seed, if intended to grow malt, should be taken from a gravelly soil, light and rich. If the soil in which the seed is sown be not loose and light, the crop of barley will not grow and ripen equally, which is a great defect. Yet the soil may be too loose; it may be so open as to permit the grain to expend much of its vegetative energy in shooting out roots instead of stems: the action of the roller is here indispensable. A rich or highly-manured soil is by no means the best for malt-barley. One of the perfections of this grain is, that it thrives well in middling soils, and without the expenditure of artificial aids.

A crop of barley occupies the ground but four months; a crop of bere, about twenty days less. It is not easy to distinguish barley from bere when they are threshed; the latter is darker, smaller, and lighter; its husk is thicker and smoother; and the flour of it is of a coarser quality than that of barley. Sometimes the two kinds of grain are scarcely distinguishable.

The best barley counties in England are the middle line of counties from east to west.

A barley crop is generally taken out of the ground after turnips, potatoes, or pulse; but not after wheat or oats, unless after three ploughings, and then only under certain circumstances. The crop requires to be cut down while the grain is still soft and juicy, before the straw has become hard and sapless, and the heads liable to break off. It should remain a long time on the ground, so as to dry perfectly, lest after being stacked it should heat and be damaged. When stacked, air passages should be left in the stacks, as an additional precaution against heating. If the barley has been stacked while too green, it sometimes heats to such an extent as actually to take fire. An inferior degree of heat will also do mischief; it will produce a certain degree of blackness at the germ end of the grain; and such will never be good seed, nor afford good malt. But a still less degree of heating is serviceable; this constitutes what is called *sweating in the*

mow. It takes place after stacking; the redundant moisture of some grains, arising from inferior ripening, is communicated to those which contain less; a spontaneous heat is generated, which will be moderate if the grain has not been stacked too green. It should never exceed 100°; but it often rises to 120°, or even more. Equal diffusion of the moisture is the consequence of this change; the grain now appears dry, and it seems to have become riper; it will imbibe water equally, while in steep with the maltster; and the result will be a more equal germination. Sweating in the mow is therefore of use, provided it does not run to an extreme. In the central parts of the rick it is sometimes difficult to prevent the heat from accumulating, and *mow-burning* the corn.

The separation of the grain from the husk or chaff in which it is inclosed is effected by machines of various constructions: there are three processes, threshing, shaking, and winnowing. It is a matter of difficulty to separate the awns or beard from the grain; and, on this account, the threshing-mill is often furnished with peculiar contrivances that need not be here noticed.

When barley is intended to be converted into malt, that which is the largest and heaviest, and has the thinnest skin, should be selected. It should not have sustained injury of any kind; it must be perfectly sound. It is not absolutely necessary that it should be of the fullest kind; a shrivelled grain indicates a thin skin. But an ill-thriven grain will never make a good malt.

It is of great importance that barleys intended for malting, if of different kinds, should not be mixed. The barley of different soils, of different years, size, and degrees of ripeness, will, if mixed, all malt unequally. The process of germination is sooner completed in new barleys than in grain of a former season. Small grains malt before large ones; and ripe grains afford a much more plump and rich malt than green ones.

Barley, intended for malting, should not be used new; it should always be stored in the house for some time:

for it is found by experience that what has been recently taken from the field does not succeed so well. Nor does that succeed well which has been housed early, and which has got little or no rain. The same grain will not always malt equally well; and different conditions of housed barley will occasion difference of quality in the malt. Barley which has been gathered too green will afford a poor, small, shrivelled malt.

When the growth of the barley is almost or entirely complete, and the ears are well filled, heavy rains are sure to prostrate the stems, and lay the ears on the ground; a process of vegetation then commences in the grain, after which it is said to be *malted*. This is in fact a degree of the artificial process of the maltster. The value of the grain, after this misfortune, is greatly diminished: yet it still answers the purposes of the brewer, and especially of the distiller, provided it is mixed with a proper quantity of good malt.

Barley is a bad bread-corn,—"*grossier comme pain d'orge*," is a French proverb. Barley bread is dark-coloured and doughy. Plutarch and Livy say, that the Roman generals used to punish the soldiers, who behaved with cowardice in the field, by giving them barley instead of wheat. Although not agreeable, it is tolerably nutritious. Pliny mentions that the gladiators were called *Hordearii*, because barley constituted a great portion of their food. Amongst the Romans this grain was used for feeding horses. In Ireland the still worse article of bere-bread is common amongst the peasantry: its colour is almost black. Barley is less nutritious than wheat or even oats. What is called Scotch, French, or pearl-barley, is merely common barley, which, after being kiln-dried, is deprived of its tunics or bran by a mill: the grains are rounded by trituration, and are thus cut down smaller; they are finally well whitened in their own meal. It is said that the bran contains a resin of a purgative and even acrimonious nature: to remove this acrimony is the object of taking off the bran. It is probably owing to this resin that malt liquors act as ca-

thartics to some constitutions. By long keeping, the decorticated barley becomes mealy on the surface, and the meal is generally musty and sour; hence it is to be washed away when the grain is to be used medicinally, or as an article of food. Pearl-barley was once a Dutch import: it is now manufactured in Britain. A decoction of shelled barley in water was the original *ptissana* which was so distinguished an article of ancient medicine.

CHAP. III.

ON THE NATURE AND CONSTITUTION OF SEEDS.

Before we proceed to the consideration of any of the processes to which grain is subjected with a view to its conversion into any of the intoxicating liquors, it will be necessary to enter into some details relative to the nature and constitution of seeds in general. Without this, changes would be described, as affecting parts and constituents of the seed, which could not possibly be understood for want of due acquaintance with the functions of the parts, and the properties of the constituents.

The seed of a plant is that part from which a similar plant is to be reproduced, and to the formation of which all the organs of the plant, and all its efforts, conduce. The seed is composed of several parts: the *cotyledons* often compose the main substance, of which there are generally two. Between the cotyledons lies the *corcle* or *germ*, which is the embryo of the future plant, and which by right should be considered exclusively as the seed. The corcle contains the *rostel*, which descends into the earth and becomes the root, and the *plumula*, which ascends and forms the stem. Beside these, there are the *investing membrane*, and the *scar* or *eye*, through which the seed receives its nourishment while germinating.

It appears, therefore, that the chief part of the seed is the corcle, consisting of the cotyledons, the stem, and root of the future plant. Some seeds contain but one cotyledon: this is the case with the different kinds of grass and corn. More generally they contain two, seldom more; but sometimes there are even six: in other cases, they are entirely deficient.

The cotyledon is a kind of cellular or spongy substance, in which is sometimes deposited the *albumen* or food of the embryo plant, during its growth, and before the roots are sufficiently matured to fulfil this their proper duty. The cotyledons, after having discharged the duties of a root by supplying ready-formed food to the embryo plant during germination, now assume a new function, and often, but not always, grow out of the ground and become leaves, which on account of their origin are called the *seed leaves*. These sometimes speedily wither away; and sometimes they continue growing for a length of time, and then fall off. Plants produced from seeds with two cotyledons are called *dicotyledonous:* but when there is but one, they are named *monocotyledonous*. When there is but one cotyledon, as in the different kinds of corn, the cotyledon does not rise out of the ground; the plumula only appears, and the cotyledon decays away.

The *albumen* or *white*, which is sometimes deposited in the cotyledon, and is intended to be the nourishment of the young plant before it can provide for itself, is of various natures and degrees of consistence. Sometimes albumen is horny, sometimes fleshy; sometimes it is so condensed as to be as hard as stone; sometimes it is farinaceous or floury. When there is but one cotyledon, the albumen, although often mistaken for the cotyledon, is quite separate from it. In such cases, the great bulk of the seed is albumen of the farinaceous kind: the different kinds of corn are examples of this structure.

For a certain number of days after a seed has been sown in the proper soil, no change takes place but the absorption of moisture, and the consequent enlargement and softening of the seed. The external coat, not having swollen

in the same degree, is burst. The rostel, or as it is otherwise called, *radicle* or *rootlet*, then sprouts forth; it strikes downwards into the earth; and its growth is effected by the transmission of a solidifiable fluid through the parts already formed to their extremities; and thus, at length, the *root* is formed. The plumula also growing through the body of the seed, soon buds forth at the opposite end; and continuing to grow, forms the *stem*, from which, in process of time, sprout the leaves, branches, and flowers. But at this period of germination, the vital functions are not sufficiently energetic to nourish both the rostel and plumula at once equally: hence the latter is more backward. Thus, during the first growth of the seed, the corcle shoots out in two opposite directions, the rootlet downwards, the plumula upwards; and this happens in a wonderful and constant manner, be the position of the seed in the ground what it may. Each seems to seek its appropriate stimulus, air being the stimulus of the plumula, and water that of the rootlet. The assumption of vegetable life and activity by these two parts, as manifested by their growth, constitutes a peculiar and interesting process, to which the name of *germination* has been given.

Thus the corcle is a part of the seed of the greatest consequence. The more important of its two members is the plumula, for its existence is indispensable in every seed: but it is known that the rootlet is sometimes deficient. The cotyledon is of course absolutely necessary, inasmuch as it contains that food, without which the germinating plant could not live.

Every one knows, that seeds are preserved for store by drying; and that some of them may be kept in their ordinary dry state for a surprising length of time without change. When buried immediately under the surface of the soil, they very soon begin to grow. Now it is to be enquired, what difference does the presence of the soil occasion. If seeds be planted in perfectly dry earth, they will not grow: but if the earth be moistened with water, they do not long remain inactive. Hence

the presence of water is necessary. The next question is, does it matter whether the water is in the solid or the liquid form;—or, in other words, will the freezing temperature permit a seed to germinate? Common experience proves, that seeds never grow when the moisture of the earth is frozen: hence a temperature above 32° (i.e. freezing), at least, is necessary; and sometimes the temperature must be considerably higher. Well-established experience also proves, that if seeds are buried so deep as to prevent the contact of the atmosphere, they refuse to grow: and that if brought up so near the surface as to have a free supply of air, they will then vegetate freely. It might, perhaps, be considered doubtful, whether, in this case, the true life-exciting influence might not have been the *light* rather than the air. But seeds are found to germinate, at least as well, when excluded from light, by covering them with the soil. Some have even maintained, that light is so prejudicial as either to prevent germination altogether, or to occasion a sickly growth. The practice of those persons, whose interest it is to be acquainted with the influence of light, in germination, shows what their opinion is: malt-houses are so constructed as to exclude the light, when the grain is under process. But is the opinion of maltsters well founded? In answer to this question the observations of Dr. Irvine seem well entitled to consideration. It is known to every body, he says, that vegetables do not arrive at any degree of perfection, when made to grow in a dark place, and never contain any thing but an insipid watery juice. If a ray of light is admitted, the vegetable grows with greater vigour, and directs itself to the aperture by which the light entered. Even different degrees of light produce sensible differences. Vegetables growing in a situation most exposed to the sun have the richest juices, as appears plainly in the case of grapes growing on the sunny side of a hill, they being much sweeter than those of the same species grown on the south side of it. One might expect that the sweet matter in grain, beginning to vegetate, should also be affected by light. The seeds

of plants, growing below ground, may, indeed, be supposed to be little affected by light: but they are not altogether out of the reach of its influence, as is evident from comparing the growth of seeds in different pots of earth, some exposed to light, and others kept in a dark place, the heat in all being equal. Perhaps part of the difference of sweetness, observable in different grains of malt, may arise from different degrees of light to which they had been exposed during their vegetation.* So far of light.

Since, then, the presence of air is certainly necessary to germination, and since air is known to consist of two different kinds of air or *gas*, one called *oxygen*, the other *azote*, it becomes a question which of these gases is the one essential to the process: or is it the air, in its common atmospheric form, that is, a mixture of both the gases, that is required?

It has been proved by the researches of various chemists, that seeds will not vegetate in azote; and that vegetation will not take place in any gas, unless oxygen be contained in it. In short, it is a proved fact, that oxygen is the portion of common air which is indispensable to the growth of seeds. But there can be little doubt, that azote is useful in modifying and moderating the otherwise too powerful stimulus of pure oxygen gas, during the subsequent growth of the plant. The same moderating quality is observable in the process of life and of combustion: hence the use of azote in the atmosphere.

It has been even ascertained that supplying oxygen in a condensed and separate form, disentangled from the affinity of other bodies, will produce germination in seeds which had been proved incapable of growing in the natural way. Thus the liquid which chemists call *chlorine water*, and which is indirectly capable of affording oxygen, in a manner not necessary to describe, has been successfully used to revive the dormant vitality of very old seeds, by steeping them in it for a short time.

* Irvine's Essays, 333.

Or perhaps it may be hereafter discovered, that chlorine itself is as efficient as oxygen; and that, in these cases, it was not the oxygen that revived the seed, but the chlorine. This, however, is not the opinion of the present day.

As soon as oxygen has been absorbed by the growing seed, that gas is returned again, in precisely the same volume or bulk, but altered into *carbonic acid gas*, by having dissolved away some of the *carbon* or charcoal which constitutes a part of every seed and every vegetable substance, and which may be rendered manifest by *charring* or scorching, the black remaining substance being carbon. The quantity of oxygen gas absorbed, and consequently of carbonic acid returned, is inconsiderable, as will hereafter appear.

Thus the chief circumstances to be attended to in causing seeds to germinate, are to supply them with water, heat, and air. If too much water be admitted for a continuance, the consequences are as fatal as too little; the seeds will not grow. When seeds are collected in quantity for keeping, they are dried; that is, the water is evaporated from the albumen of the cotyledon; and hence the albumen being thus condensed, and rendered hard and solid, it is unfit nutriment for the young plant. On this account no increase of substance or quantity of matter can be given to the embryo; it cannot grow, or, in other words, it cannot effectively exert its tendency to assimilate its food; but if the seed be totally immersed in water, unless it is the seed of an aquatic plant which grows altogether in water, the consequence will be, that the aliment of the young plant is totally dissolved away; hence its vital functions cannot be exerted, and decay and death terminate its organic existence.

With regard to temperature, it must be observed, that exposure to the freezing point, or to a lower degree, is by no means fatal to the vital principle of seeds. All that is intended to be said is, that unless the temperature is above 32°, the seed will not germinate *at that time*: but it may at any other time, when the temperature is

sufficient. Different plants require different degrees of heat during their growth; but so far as mere germination is concerned, the difference of heat required seems not so considerable. During the heat of spring and summer the germination of seeds is much more readily produced than in winter, and in warm climates the same seed will germinate more speedily than in cold ones. It is also a fact, and it will appear more fully hereafter, that when a genial warmth has once excited the germinating process in a seed so as to produce actual growth, the temperature spontaneously rises, and maintains itself in a manner somewhat resembling the preservation of heat in the bodies of living animals. When a great quantity of seeds is made to germinate in a heap, the elevation of temperature often rises so high as 150°. It is not merely during germination that this heat is observable; it may be perceived also during the more advanced growth of the plant. Thus the snow which falls on fields thaws sooner than that which falls on the bare earth. And at certain periods of the growth of some plants, a very considerable elevation of temperature has been indicated by the thermometer. In one instance the flower of a plant was found to be 16 degrees warmer than the surrounding air, and this heat was maintained even until midnight.

It is truly astonishing how long the vital principle can be preserved unextinguished, although dormant, in seeds, when they are placed under such circumstances as will prevent either putrefaction or germination. Corn was found at Herculaneum, which had lain buried for more than seventeen centuries, and was then in good preservation.* Seeds brought from Herculaneum have since grown in Britain. There are also several other instances on record, where seeds have been buried in the earth to great depths for centuries; yet as soon as the soil which contained them was accidentally brought to the surface, and exposed to the air, they began to germinate, the stems were developed, and they produced

* Cochin and Bellicarde's Herculaneum, p 49.

flowers and fruit. These facts are not more surprising than others relative to suspended animal life, which are well authenticated: live frogs and lizards have been disclosed on breaking solid masses of stone, which had been incarcerated in this rocky prison during a period now not ascertainable. By the examples given it is proved how indispensable an agent air is to the resuscitation of life in a seed, when its vegetable animation had been suspended by the process adopted for its preservation. And if another proof were required, we have it in the fact, ascertained by several experimentalists of authority, that seeds will not germinate in the exhausted receiver of an air-pump, even although otherwise placed, under favourable circumstances.

Although, in order to induce germination in seeds, they are generally sown in the earth, it is well known that earth or ordinary soil is not essential to the process: they have been made to grow in sand, in powdered Derbyshire spar, in metallic oxides, in flowers of sulphur, and on moistened flannel. In short, the use of soil is quite secondary to the effects of air, warmth, and water; although the soil at length becomes the proper medium, in which alone the plant can arrive at full perfection.

It may be here noticed, that if a seed has germinated, and if the further evolution of the plant is checked, by drying off the moisture of the seed, its vital principle is extinguished for ever; and no artificial process can cause it ever to grow again: it is now merely vegetable inorganic matter. It is also necessary to observe, that when a seed is kept moist for any considerable length of time, it not being exposed to air so as to permit germination, its vitality is also destroyed, and the seed soon runs into putrefaction.

It has been already observed, that when a seed is deposited in the earth, under the proper conditions of air, temperature, and moisture, the bulk of the seed is increased, the external integuments burst and decay, the rootlet shoots downwards, and grows into a root; while shortly after the plumula ascends, and at length forms the stem. This increase of parts argues an increase of

substance; and the question suggests itself, whence is this supply of matter derived? Although the supply during the growth is obviously derived from the soil, this cannot be the case at the commencement of germination. The rootlet, at its first evolution, is too small to come effectually in contact even with the particles of soil: it is an equal chance that it lies in the space between two particles; in which case it certainly cannot derive its supply in that way. But, fortunately, the embryo is quite independent of this adventitious supply: it has its own magazine of provisions, deposited in its cotyledons for its support during its early infancy, and with this magazine it has a continuous communication. In the cotyledons of a seed may be discovered a kind of channel called the chyle-bearing duct (ductus chyliferus). During germination, it may be observed that this duct ramifies throughout the cotyledons; and it will be found that all these ramified vessels join each other at the corcle and open into the rootlet: thus an open communication is formed between the rootlet and all parts of the cotyledons. But there is no direct communication between the plumula and these ramified vessels: the plumula only communicates with the rootlet. We now plainly perceive that the root, when perfect, is not only the source of supply to the mature plant, but that even while it was the rootlet, it was the source of supply to the whole germ.

The albumen is the natural food with which nature has provided the young plant until, this being exhausted and the root sufficiently grown in the soil, the plant can derive its support from external sources. But we are not to suppose that the albumen is the indispensable and only food which the embryo plant is, in any case, capable of assimilating. On the contrary, experiments have been made in which the germ was extracted from the cotyledons, and planted in moistened earth: some did grow, and some did not; but those that did grow were exceedingly stunted in size, and very short-lived.

It appears, by the organisation just now described,

that the albuminous food can be drawn by the rootlet from all parts of the seed where the albumen is deposited, and that from the rootlet it can be transmitted to the plumula. But it has been already stated that the albumen is often exceedingly hard, horny, and condensed; and food of this kind, as is obvious, could not be transmitted through these capillary ducts, without undergoing some important change resembling in its objects the digestion of the food in animals.

That a change of a most important nature does take place is obvious, from the fact that the albumen acquires new characters essentially different from those which it originally possessed; and now it becomes our object to trace what the nature of this change is, and how it is effected.

The first question is, What is the *albumen* which we find deposited in seeds? The word, when that of seeds is meant, seems to be a name to which no very precise meaning has been attached: it is a specific name, and probably its individuals are as numerous as the seeds themselves; or, in other words, perhaps every seed contains an albumen proper to itself. It is essentially different from the albumen of chemists, whether vegetable or animal, neither of which has indeed been hitherto rightly distinguished. In short, it merely expresses the food provided by nature for the embryo contained in the seed; and its name neither refers to any particular composition, nor to any identity with synonymous words.

Familiar examples of the variable nature of the albumen of seeds occur in the different kinds of grain, in peas, beans, &c. We know, for instance, that although rye-meal, barley-meal, wheaten-meal, and oaten-meal resemble each other very much in their general properties, there are differences amongst them with which every one is acquainted. The meal of beans, peas, and other papilionaceous plants, is essentially different from all the rest. The examples shall be taken from the different nutritive grains, because their constitution is better understood, and because they have direct relation to the chief object of this volume.

Chemical analysis puts us in possession of the essential differences between the albuminous portions of seeds; and a few of these shall be adduced to prove their variable nature. Rye-meal contains starch, saccharine matter, gluten, true vegetable albumen, and mucilage. Wheaten-meal consists of the same principles, along with some phospates. Barley-meal contains all the preceding ingredients, beside a fixed oil, and some volatile matter. Rice consists of very nearly the same materials as barley, except that fixed oil has not been found in it, and that in place of gluten it contains a peculiar vegeto-animal matter. In all these grains it is observable that the ratio of the ingredients is different; but in all of them, *starch*, otherwise called *farina*, is not only a constant but an abundant constituent. Starch is also a nutritive principle of all grains: it has been analysed by several chemists. The two analyses which most nearly approach and therefore support each other best are those of Berzelius, who experimented on potato-starch, and Gay-Lussac and Thenard, who used wheaten-starch. These analyses having been executed by eminent chemists, it will be but reasonable to adopt the mean of both as nearer the truth. The two analyses and the mean will then stand thus: —

	Berzelius.	Gay-Lussac and Thenard.	Mean.
Carbon	43.481	43.55	qu. pr. 43.51
Oxygen	49 455	49.68	49.57
Hydrogen	7.064	6.77	6.92
	100	100	100

Reflecting on these analyses, we cannot fail to be struck with the similarity of the analysis of sugar, in point of ingredients, as well as proportions. And it will be of importance if we refer to the analyses which have been made by the same chemists of sugar, taking the mean of both as before:

	Berzelius.	Gay-Lussac and Thenard.	Mean.
Carbon	44.200	42.47	qu. pr. 43.34
Oxygen	49.015	50.63	49.82
Hydrogen	6.785	6.90	6 84
	100	100	100

The result of these statements is, that starch and sugar are composed of precisely the same ingredients; that the only discoverable difference is a slight disagreement in the relative quantities, and that this is exceedingly trivial. By comparison of the two means, the following are the differences: one hundred grains of sugar contain about one seventh of a grain less carbon, about three eighths of a grain more of oxygen, and two ninths of a grain more of hydrogen than are contained in one hundred grains of starch. These are trifling differences; and, without reference to atomic considerations, it will immediately strike the enquirer that differences by far greater than these frequently occur in the analyses of the same body executed by different chemists, or by the same chemist at different times; and, in illustration, I adduce the analyses of sugar by the chemists already quoted, wherein the quantity of carbon, as stated by Berzelius, is very nearly two grains more than what is stated by Gay-Lussac and Thenard. In short, we may conclude that analysis has not been hitherto able to detect any difference of composition between starch and sugar; and we may admit that, in both, the ingredients are the same in quality and quantity. A person who contrasts their strikingly different properties; who considers that starch is one of the most insoluble bodies, at least in cold water, and sugar one of the most soluble; that sugar is the sweetest of all substances, and starch the most tasteless; will naturally enquire how are these facts to be reconciled; and if the composition is the same in both substances, why are not the substances identical. The question is natural: at least it would have been natural and necessary some time since, when it was supposed that similarity of ingredients and of proportions should produce similarity of qualities. Modern discoveries have proved that this is a mistake: it is now known that, beside quantity and quality of ingredients, the peculiar mode of combination of them is to be taken into account; and although we know, in fact, nothing about the modes of combination in which bodies exist,

yet chemists have been, in a manner, compelled into this mode of explanation by the impossibility of explaining it otherwise in the present state of knowledge. In the case of starch and sugar, therefore, we know that the ingredients are the same; we may infer that the relative quantities of them are also the same: but to assign a reason for the difference of properties, we say that they are differently combined, without pretending to say whether the difference is a closer approximation of particles, so as to expose them more effectually to each other's modifying powers; or whether it depends on some other cause. Considerations of relative specific gravities give us no information on the subject.

Be this as it may, one would be induced to conclude that similarity of composition would give origin to a great facility of converting one substance into the other; and this is just what we find to be the case in practice. A statement of a few cases of the conversion of starch into sugar will be necessary to support this position.

A mixture of starch and water, if exposed to each other's action for a length of time, as two years, no matter whether in the air, or in the exhausted receiver of an air pump, will be found much altered. The starch is changed into other substances, one half of it being actually converted into sugar. It is also known, that if starch and gluten be mixed with hot water, and allowed to act on each other for a sufficient time, the starch will become sugar. But it is a singular fact, that if starch, without any admixture, be boiled in water, for some days, we obtain a bitter instead of a sweet substance. These subjects will be resumed hereafter.

But it is possible to convert starch into sugar in a much more decided manner. If a quantity of starch, no matter whether obtained from wheat or potatoes, be boiled with water acidulated with sulphuric acid, incessantly during a few hours, occasionally adding water as it evaporates, so as to preserve perfect fluidity; then saturating with lime; continuing the boiling, after separating the sulphate of lime until the solution be concen-

trated; a dark, syrupy liquid is obtained, which, on cooling, affords abundance of sugar, in crystals. This sugar certainly differs, in some respects, from common sugar; it is not quite so sweet, nor so soluble in water; it crystallises differently; it is fusible at a much lower heat, and its solution ferments without the addition of yest. It has been ascertained that, during the whole process of its formation, not a bubble of gas is discharged; that the sulphuric acid remains unchanged; and that the contact of air is unnecessary. These facts appear to countenance the supposition just now suggested, that starch and sugar are the same in composition, and that the conversion is effected by some unknown agency of the sulphuric acid in altering the mode of combination in which the carbon, oxygen, and hydrogen are held together. One hundred parts of starch, when thus converted into sugar, become better than one hundred and ten parts; and this sugar is convertible, by fermentation, into alcohol, like any other kind.

This production of sugar is not confined to potato or wheaten starch; rice-starch has been changed into sugar by the same process. The sweetness of frost-bitten potatoes seems to be owing to a spontaneous conversion of starch into sugar. But, according to M. Pescier, potatoes naturally contain a little sugar.

We can also convert starch into sugar by a much more simple process than boiling with dilute sulphuric acid. When grains of wheat, barley, bere, oats, or maize, are sown in the earth, under proper circumstances of air, heat, and moisture, as soon as germination has commenced, and continued a little time, it will be found that the farina has disappeared, in a great measure, and that its place is supplied by a saccharine matter of a peculiar kind. It is very sweet; it readily dissolves in water, and forms a syrup, which, if evaporated, acquires almost precisely the sweetness and flavour of treacle. This case of the conversion of starch into sugar is not very different from that first described, where a mixture of starch and water, long exposed, was partly con-

verted into sugar: the vegetating process of the grain seems to have merely hastened the change. Maize affords the most striking results.

We are now prepared to understand what the nature of the change is by which the albumen of seeds, as it is improperly called, is altered from a hard, or farinaceous, or horny substance, to the soft and readily soluble food which is adapted to the feeble assimilating powers of the embryo plant, just germinating in the cotyledons. This was the subject which led to our enquiry into the convertibility of starch; and we now perceive that what is called albumen, the chief ingredient of which is starch, is, in fact, changed into sugar, not precisely similar to cane sugar, but a saccharine principle better fitted as food for the infant plant, and much more adapted than the original horny insoluble matter of the seed to enter into those ramifications of vessels which open into the rootlet, and are intended to convey to it its nutriment.

Art has taught mankind to imitate nature in this most important process of converting starch into sugar, by means of germination. What is taking place in a seed sunk in the ground cannot be seen; and a great quantity of seeds once sown in the earth cannot be recovered. On this account the process of sowing is altogether dispensed with in the artificial method, and all the necessary stages of germination are thus brought about, with as much energy, although without the assistance of the soil.

The process by which these changes are brought about is called *malting;* and as society is constituted, it is one of prime interest to mankind; the outline of it is as follows:—The grain is steeped in cold water during a certain period; the water is then allowed to drain off; the grain is spread out in a deep heap; it gradually heats; the rootlets begin to shoot out; afterwards the plumula begins to grow; and when this has grown to a certain extent within the grain, the further germination is checked by exposing the grain on a kiln, heated by fire to such a degree as extinguishes the vitality of

the seed. At this period it is found that the starch is, in a great measure, converted into saccharine matter. The result of this forced germination is, like that of the natural one, the assimilation of the natural food of the embryo plant to its wants during the first stages of its growth, before its roots are capable of providing for themselves. It is now necessary to enter into some more minute details of this subject.

CHAP. IV.

MALTING.

SIMPLE as the operation of malting may appear, it is one in which the exercise of much practical skill and much experience is required; and as it is the fundamental process, on which depends the success of all the subsequent steps adopted by the brewer or the distiller, it will be absolutely necessary to enter into many of the minute particulars to which the maltster has to direct his attention. It is a fact, which must strike the most superficial observer, that the structure of the kernel of a barley-corn is, in appearance, very different indeed from that of a grain of malt. The kernel of raw barley is heavy, hard, horny, and in a slight degree transparent. The kernel of a well-malted grain is light, soft, floury, and perfectly opaque. The cause of these differences should properly be sought in the analysis of grain in the two different states.

The analysis of barley-meal has been attempted by two chemists, Einhoff and Proust; but the results are so extremely discordant, that there is but little use in adducing either of them. There is, however, a statement made by Proust which it would be improper to neglect. He affirms that barley contains a peculiar proximate principle, which, from the Latin name of the grain, he has called *hordein*. He describes it as a yellow,

woody powder, granular to the touch, and resembling sawdust in appearance. It is insoluble in water, either boiling or cold.* In the process of malting, this hordein disappears in great quantity, and it is resolved chiefly into starch and sugar; certain quantities of which had previously existed ready formed in the raw barley. According to Proust, the following is a comparative estimate of the principles of unmalted and malted barley in one hundred parts:—

Yellow resin	1 part in barley, and	1 in malt	100 parts.
Gum	4 parts	15	
Sugar	5	15	
Gluten	3	1	
Starch	32	56	
Hordein	55	12	

The analysis of Einhoff, beside adding albumen, volatile matter, and phosphate of lime to the foregoing ingredients, represents the quantity of starch to be more than double what is stated by Proust; and if to the starch we add the hordein, still the sum will not reconcile the analyses. The proportion of sugar corresponds in both estimates almost precisely. But the most remarkable circumstance in the whole is the total omission of the fixed oil which exists in barley, and which has been described by Fourcroy and Vauquelin as amounting to a hundredth part †; and afterwards by Dr. Thomson. This oil is of importance: it is of so permanent a nature as to escape alteration in the processes of fermentation and distillation; for it is obtained abundantly in the distillation of whiskey, in shreds.

A few years since I collected upwards of a pound of this oil. In some of its properties it resembles oil of roses obtained by distillation; it is concrete, and almost as solid as tallow, even in summer: by peculiar management it may be made to crystallise in blades; it is somewhat soluble in alcohol, and may be precipitated from its solution by the affusion of water. The precipitation of this oil is the cause of the slight milkiness

* An. de Ch. et de Ph. v 340. † Phil. Magazine, xxv. 182.

which appears when strong spirit is mixed with water in certain quantity. The oil is volatile, and distils over with water: it dissolves oxide of copper, and forms a green compound: the colour of the oil, when newly distilled from wash, is variable; sometimes being pale green, sometimes white, and sometimes of no decided colour: time renders it rancid: its natural smell is not agreeable; it mostly resembles distillers' *faints*: when dissolved in somewhat diluted alcohol, it communicates to it very nearly the smell of what, in Ireland, is called *potteen* whiskey; and good judges were deceived by it. What is called the *whiskey smell* of spirit is owing to a small quantity of this oil held in solution. It is not so volatile as alcohol: hence frequent rectifications of common spirit afford a product having less and less peculiar smell: hence, in the distiller's process, the singlings contain much oil, because they were distilled at a high temperature, on account of the great quantity of water present: hence, the spirit produced first in the rectification of singlings is much freer from oil than the latter portions, when the temperature rises; and hence the very last products from the singlings have so disagreeable an odour, because then the oil comes over abundantly. The points of resemblance between this oil and oil of roses are their solidity, their volatility, their leaving a greasy stain on paper, which requires a strong heat to expel, their tendency to rancidity, their crystallisability, and the uncertainty of colour. The properties just explained place these two oils as the link of connection between what are called fixed and volatile oils. From this account it will be seen that this oil differs essentially from that obtained by M. Pelletan from potato spirit.*

Dr. Thomson is of opinion that the hordein should not be considered a peculiar proximate principle; and that it is merely starch in a particular state, somewhat similar to the fibrous matter of potatoes. Malting converts it partly into sugar, and partly into common starch,

* An. de Ch. et de Ph. xxx. 221.

by destroying a certain unknown glutinous substance, which glues the particles of it so firmly together.

It appears to me that Dr. Thomson has not assigned sufficient reason for doubting the existence of hordein, as a peculiar principle; and that the composition which he assigns to it, namely, starch in a peculiar state, its particles being glued together by an *unknown* substance, is hypothetical. If it be an unknown substance, we are but assuming the existence of one body, to remove the necessity of admitting the existence of another. The presence of substance in barley-meal in so great a quantity as more than one half of the whole weight; its being woody, and insoluble in water whether cold or boiling; its disappearing during the malting; and the increase of the gum, sugar, and starch, in consequence; are properties not attributable to any component part of any grain with which chemists have hitherto been acquainted. Hence, in strictness, I think we are bound to admit hordein as a peculiar substance.

Yet there are difficulties attendant on this admission. If, during the malting of barley, the additional saccharine and starchy matters formed are produced from the altered hordein, how is the production of saccharine matter explained, during the malting of wheat, which, according to Proust, contains neither hordein nor any principle corresponding with it. Analogy would lead us to suppose that by whatever means saccharine matter was formed in one malting process, so it would in another. But analogy is, in such cases, a bad guide; sugar may be formed either from hordein or starch; and there is little use in puzzling ourselves with difficulties of this kind, which altogether seem to be matters more of curiosity than use: the question is merely noticed here as a result flowing from the fact stated by Proust, but certainly not with a view of impugning the fact itself. Facts are the goal of science; opinions are the paths leading to it.

As to the original question just proposed, and which brought the investigation of Proust under consideration,

it still remains to be answered, what is the cause of the difference of their mechanical structure. And although the analyses of Einhoff and Proust differ so materially as to shake our confidence in one or other, and therefore for the present in both, they nevertheless agree in some essential points, and from these we may derive much information on the subject of our present enquiry. Both chemists agree that raw barley, amongst its other ingredients, contains gluten, gum, and sugar; and there is even tolerable accordance in the quantities assigned. One hundred parts of barley-meal contain about $3\frac{1}{2}$ parts of gluten, $4\frac{2}{3}$ of gum, and $5\frac{2}{3}$ of sugar. Now these are all of a glutinous nature, calculated to bind the starch and the other ingredients into a solid mass of great hardness, such as we know a barley-corn to be. For such is the hardness of gluten, that it has been used to join fragments of pottery. The following is a fact illustrative of this statement: — If barley, reduced to the finest powder and the husk removed, be made into a paste with water, rolled into grains resembling the original barley, and exceedingly well dried before a brisk fire, but not scorched, they become almost as hard as the natural grain. But this powerful cohesion has taken place between particles which had been already disintegrated, and removed from each other. How much more powerful must be the cohesion of particles bound together by gluey matter, which had grown along with the ingredients of the corn, which cemented — not particles formed by the artificial process of grinding — but the ultimate particles of which that kind of matter is composed. In such a case, it is not wonderful that particles so much more closely approximated, and so much more intimately penetrated by the cement, of which two of the ingredients are perfectly transparent, and the third a good deal so, should be so affected as to be at least horny, if not in a slight degree transparent, as we find a ripe dry barley-corn to be.

But when barley is steeped in water, with a view of

malting, the cement is softened, the particles now cohering with but little force, are separated to a greater distance from each other, so that the specific gravity is lessened by the absorption of water and consequent swelling of the grain, and perhaps by the evolution of the carbonic acid. During the progress of germination, the quantity of the chief cement, the gluten, is lessened from three parts to one, by chemical changes in it; and, in short, the whole constitution is subverted.

It is matter of opinion, admitted by some and denied by others, that the change effected in barley by malting is complete; that it affects every ingredient of the grain; and that the whole substance is converted into new matter, which did not previously exist in the grain. What the nature of this new matter may be is not yet agreed on. There are two opinions. It is found that hot water is capable of dissolving away every thing from malt, except the husk. This, it may be supposed, could not happen unless there was a total change effected in the starch and gluten of the barley. Starch, it is true, is soluble in boiling water; the result, however, is not a solution, but a well-known jelly, which becomes even more stiff by cooling. But the solution obtained from malt is perfectly fluid, whether hot or cold. From the disappearance of the starch, and the obvious formation of sugar, it has been supposed that the result and object of malting are the total conversion of the starch into sugar.

But a different view may be taken. It may be supposed that, during the malting process, the change of starch into saccharine matter is but partial; that the malt still contains much unaltered starch; and that, by the action of hot water, the conversion into saccharine matter is nearly completed. In short, it has been conceived, and with much probability, that the sugar-forming process is resumed and continued during the action of the hot water. It is difficult to determine which of these views is correct: the subject is obscure, and requires fuller investigation. The consideration of it shall be

resumed in its proper place. It is sufficient, for the present, to observe that the latter opinion is by far the better supported of the two.

Malt returns to the state so considerable a revenue, that its preparation is watched with the most vigilant scrutiny. The determination of the form and measurement of the apparatus by which it is produced constitutes a part of the law of the realm; and the whole process is embarrassed by legislative restrictions of such a nature as to prevent the likelihood of improvement.

On the subject of the season when malting can best be executed, there is difference of opinion, not here necessary to discuss. It is certain that summer is a bad time: the natural heat of the weather, along with the chemical evolution of heat from the grain under process, conjointly occasion such a modification of the changes, that instead of sweet malt, we obtain it bitter and comparatively valueless. Of this the consumers are sufficiently aware, and they cautiously avoid, or should avoid, malt made during any other period than the cool season of the year. May is the latest month in which it should be made: any malted after, is called *latter-made malt.*

The whole process is divided into four stages; they are called steeping, couching, flooring, and kiln-drying. These shall be separately considered.

Steeping.—By acts of 7th and 8th of his present majesty, it is declared, that in malt-houses where more than eight bushels of corn are steeped at a time, the cistern employed shall be permanently constructed, with the sides and ends thereof straight, and at right angles to each other, and of no greater depth than forty inches, with an even bottom, having an inclination for the drip of no more than half an inch to every foot in length. The cistern is lined either with lead or stone, and is commonly sunk in the earth. In general there are many such in one malt-house.

The barley being thrown in, water is poured over it until it stand as many inches over the grain as the latter

is expected to swell. The whole is then mixed up. The good barley sinks, it being specifically heavier than water, while that which is light and unfit for malt floats, and thus affords a facility of removing it, which, to save duty, is accordingly taken advantage of. It is of importance that the water should be of the purest quality: brackish water, or water which contains any bad taste or smell, will do harm. Rain or very pure river water is best; and hard water may be rendered fit by due exposure to air, and boiling.

As the steep-water dissolves away some bitter yellow matter from the husk, it is generally removed after awhile, and new water is immediately let on: by law this is only permitted to be done once, although in warm weather it may be necessary more than once, especially should the steep-water become sour and mucilaginous. The whole period of steeping, as determined by law, is to be not under forty hours, nor to exceed fifty-five hours, unless notice be given to the excise officer; and then the time may be extended to sixty-five hours, but not beyond it. Within these limits the malster may exercise his judgment: as the weather is cold, the time of steeping is to be long; the time is to be also long in proportion as the grain was dry; and short, as the grain was old. Bere requires less time than barley. But some experienced persons are of opinion that the major limit of time allowed by law may in some cases prove much too short. Mr. Collier says, "that, generally speaking, sixty hours are sufficient." Be the time more or less, the proper criterion by which it may be judged when the corn is sufficiently steeped, is to hold a grain, taken from about the middle of the heap, lengthwise between the first finger and thumb; and if, on using a little force, it readily breaks down into a pulpy state between the fingers, it is sufficiently steeped. At this period the grain is much swollen, and a little carbonic acid has been emitted. After the barley is saturated with water, it must be removed: if not, it is robbed by the water, as appears by the fact stated

by Mr. Collier, namely, that the water will then be capable of fermenting and affording alcohol. In all cases the barley loses a little.*

There is a mal-practice amongst maltsters which often occasions the worst consequences to the brewer and distiller, that is, the culpable negligence of not assorting the different parcels of barley that are intended to be malted, but steeping them all promiscuously in the same cistern. A careful maltster will keep separate the parcels of grain which have grown in different soils or districts: he will avoid mixing old and new barley; and he will even separate the large from the small grain of the same batch, by the process of screening. The different qualities should constitute different batches for steeping. If these particulars are not attended to, the consequence will be, that when the mixture of the different qualities is put into the one steep, the grains will not germinate equally; the germination of some will have proceeded considerably, while that of others will not have yet commenced. In some grains the saccharine matter will be exhausted, in others it will not be yet formed, and the whole product will be malt of a very inferior quality. This must necessarily happen, for in the case of different sizes it is obvious that the same steeping that will be barely sufficient to penetrate a large grain will oversteep a small one; and *vice versâ*. Hence, after equal steeping of unequal grains, the small ones may grow too much, and the large too little. With regard to different ages of barley, it must be remembered that time very much modifies the qualities of many seeds. Thus, every one knows the practice of gardeners, who, when they wish to restrain the luxuriant growth of a plant, keep the seeds by them for some years, and the object is thus certainly attained. The brewer or distiller who is his own maltster can always protect himself from injuries of this kind; but he must always be subject to them while he depends on others for the execution of this fiducial office.

* Manchester Memoirs, v. 255.

Couching. — This is the second process to which the grain is subjected. After steeping, the water is drained off; and the malt, now heavy and much swollen, is removed to the couch-frame, which is thus defined by law: — "Every couch-frame shall be constructed with the sides and bottoms straight, and at right angles to each other; three sides being permanent, and the other side formed by moveable boards of the substance of two inches, at least, in thickness: such couch-frame to be supported on the outside, so that the same may not bend or curve, or fail to preserve, when filled with corn, the same dimensions as when empty; in order that the officer may be enabled easily to gauge the grain contained therein."

The grain is to fill the couch-frame to the height of thirty inches, according to the act; and it is directed to be laid perfectly level for facility of gauging. The space of time during which it is to lie there is also defined by law to be twenty-six hours, at any time from the first of March to the first of December; or thirty hours at any other period of the year: but it is not enacted that it shall remain no longer. During this time the grain begins to heat somewhat; it also becomes dry on the surface. Were it, at this period, spread out thin, instead of being in a heap, it would merely dry without heating, or germinating. In about four days after it has been placed in couch, the grain again becomes moist: this is called *sweating;* and it remains so during one or two days, and then the moisture disappears At the same time a smell, compared to that of apples, is perceptible. And if some of the grain be now distilled in a steam bath, a little diluted alcohol will be obtained. Towards the middle of the heap, where the heat is greatest, the rootlets, at the time of sweating, begin to shoot; and this is warning that the third process has become necessary.

Flooring. — The contents of the couch-frame are now to be well mixed, so as to equalise the temperature; and the heap is to be spread out into thinner strata, which are called *floors.* The object is as follows: — At this period

the chemical action which produces germination has commenced; it has produced heat. The heat is apt to rise considerably, especially in the middle of the heap. Germination would then proceed with dangerous rapidity in that part; the saccharine principle would there be exhausted, while in other parts the vegetation would not have commenced. Hence an equal quality of malt could not be obtained; there would be no sugar present, it being exhausted in one portion, and not yet formed in the other. The malt, by over-heating, would have become bitter. The heap is, therefore, well mixed, and spread out into thinner heaps. After a while, the heat rises again; and now it must be constantly turned, as well to equalise and moderate the heat, as to expose new surfaces of grain to the air, which is so indispensable an agent in the process. If the weather be warm, the turning must be more frequently repeated; perhaps every four hours will suffice: if the air be cold, the intervals may be double that period. In short, it is here that the skill and attention of the maltster are required, to render the germination of the barley equal in every corn: for without this, the resulting malt will never be equal in nature, nor produce the full quantity of saccharine matter, nor good worts. The heat, during the first ten days, should be preserved, if possible, below sixty degrees; and as the malting season is the cold period of the year, this is several degrees above the temperature of the atmosphere. The heat then gradually rises, within two or three days, to about seventy degrees; and afterwards often to ninety degrees, beyond which it should never go, although it sometimes does exceed it. As may readily be supposed, it is both more necessary and more difficult to moderate the heat during warm weather, as well as when the quantity of grain operated on is considerable.

In proportion as the heat rises, the heaps should be spread out thinner and thinner: the larger the surface exposed, the more quickly the heat is carried off. At the time of the sweating, the rootlet, at first consisting

of three fibres, and afterwards of more, is fast growing. And in proportion as the growth proceeds more or less rapidly, the turning must be more or less frequent, and the heaps more or less thinly spread. The tendency of the grain to expend its vegetative energy in forming roots of inordinate length will thus be checked; otherwise the roots would run out two or three inches long, although half an inch is the length which they ought not to exceed.

The day after the rootlet has shot out, the germ begins to grow, or to *come*, as it is technically expressed. The germ is by maltsters called *acrospire*. It springs from the same point as the rootlet had done; and both of these members grow the opposite way to each other. But the growth of the acrospire is both slower, and, by art, is rendered more limited than that of the rootlet. It grows between the cotyledon (or kernel, as maltsters call it) and the husk: hence it grows unseen; and it can be only traced by the ridge, which its increasing bulk occasions on the back of the grain opposite the scar. When the acrospire is known, by the length of the ridge which it forms, to have grown about three quarters through the whole length of each grain, or just up to the inward skin, it is the signal that this stage of the process is complete. This generally happens in about fourteen or fifteen days from the commencement of couching. If the acrospire grow entirely out of the grain, so as that the top of its plume extends ever so little beyond the end opposite to that out of which the rootlet has sprouted, the malt is injured. Some of its saccharine matter has been withdrawn to supply this unnecessary growth; the malt is, therefore, deficient of sugar to this amount; it is spent and poor; and the drink made from it will be vapid, spiritless, and at length will prove unsound. If the acrospire grow much beyond the extremity of the grain, the malt loses all the saccharine matter which had been formed; and it is rendered totally unfit for fermentation. On the other hand, if the acrospire is grown but two thirds or less

through the husk, the quantity of saccharine matter is also deficient, because little has been formed. Hence the due growth of the acrospire is the criterion which informs the maltster of the lucky moment when the quantity of sugar is at its maximum. There may, however, be objects in view, which render a modification of the usual practice necessary. "In some instances," says Dr. Irvine, "the vegetation is stopped before the whole farina or starch is changed into sweet matter, in order to obtain afterwards, by fermentation, a milder and more viscid, though less spirituous, liquor. When this is intended, the grain is just allowed to begin to grow; and the moment the rootlet makes its appearance, the vegetation is stopped." The saccharine matter invariably forms to the same extent in the grain as the acrospire has grown: the point at which the acrospire ends is the limit of the sugar; all beyond that is starch. If the barley had been steeped long enough to produce perfect saturation, the growth of the rootlets and acrospire is such, according to Ramsbottam, as to double the bulk of the original grain: but the volume is easily compressible.

As connected with the same subject, it may be proper to add, that while the malt is growing on the floor, it will prove highly detrimental, if, by treading or other violence, the grain should be injured, or the rootlets broken off. If the grains be damaged, they will cease to germinate; they will die, become mouldy, and change so far to the nature of vegetable mould, as to afford a kind of rich soil for the nutrition of what is still growing. Now it is known that the chief difference between the growth of the grain on the malt-floor and in the ground is, that the germ grows slowly on the floor, because the rootlets cannot draw in any foreign nutriment: but in the ground they grow much more quickly, for the contrary reason. If, while a batch of corn is germinating on the floor, some grains strike their roots into the extinct and decaying remains of others, as they frequently do, the germ of such will sprout with twice the rapidity of those that are not so circumstanced: hence

some grains will be more forward than others; and the saccharine matter of such will be exhausted. If the rootlets be broken off from any of the germinating grains, such will shoot out new rootlets; and this new effort will considerably exhaust the malt wherever it occurs. Hence, external violence is to be guarded against while the malt is on the floors, as productive of certain mischief.

About the period of the growth of the acrospire, above described, if the process has been rightly conducted, the evaporation resulting from the heat and frequent turning will have been such, that the grain, hitherto sweating, will have now become almost dry. In short, the grain contains so little moisture, at this stage, that the rootlets begin to languish; and the vegetation is, in some degree, checked. The thickness of the grain on the floor must now be increased; and, to evaporate more of the moisture, it must be frequently turned.

The vegetation, thus on the decline, must be now stopped, and all vegetable life extinguished. This purpose is effected by a process which not only does so, but produces another result just as important. It has been already stated, that vegetation can only proceed within certain limits of temperature: too low or too high a degree is equally fatal. In this case it would be possible to stop the vegetation of the grain by mere exposure to a freezing cold: but, on the return of the ordinary temperature, the growing process would recommence for two reasons; first, because there is water still present in the grain, and next, because cold does not extinguish, but only suspends the vitality of seeds. But if the grain be subjected to a high temperature, not only is the water all evaporated, but the germinating quality is destroyed: hence the state of the seed is preserved just at the degree of vegetation which precisely answers the purpose of the maltster.

Kiln-drying. — Accordingly, the malt is removed from the floors to the kiln, where the fourth and last stage of the process is commenced. The malt-kiln con-

sists of an extensive floor, composed either of wire-work or of earthenware tiles or iron plates, perforated with innumerable holes, very small at the upper surface, and much larger underneath: in effect, they are funnel-shaped. On this floor is spread out the malt: the grains cannot fall through the holes or the wire-work; but the heat arising from a fire placed underneath can readily pass through them, and act on the superimposed malt. The whole kiln is somewhat funnel-shaped, the small end downwards, containing the fire, and the wide mouth being covered with the tiles or wire-work.

The malt is spread on the kiln, in an equal but thin stratum; perhaps but four inches in thickness; sometimes more, sometimes less. It is certain, that if it be spread out too thick, it will dry unequally; the grains next the fire being over-dried, and those on the surface being not dried sufficiently. The consequence of these extremes will appear hereafter. At first, the heat of the kiln should be little superior to that of the atmosphere; one reason of which is, that a high heat would render the external portion of each grain hard and glassy, and the free evaporation of the moisture would be thus prevented. Another reason will presently appear. The temperature is therefore raised through successive degrees, until it arrive at some point between 140° and 180°, or even a little higher, according to the judgment of the maltster, or I should, perhaps, say his fancy. I am quite satisfied, that the lower the temperature at which malt is dried the better; provided that the moisture be well expelled from it, and that the vital principle has been thoroughly extinguished. The following are the grounds of my belief:—It has been ascertained that the saccharine matter of malt is a substance possessed of one very remarkable property. When extracted from the malt and insulated, it is decomposed, and even reduced to the state of charcoal, by a degree of heat under that of boiling water,—a temperature at which other vegetable substances are scarcely affected. At 180°, if kept moist, it loses its sweetness; and even at an inferior heat, it is

probable that its properties are somewhat altered. Now, with these facts staring us in the face, how can we suppose that the heat of the malt on the kiln should be allowed to exceed, by one single degree, the temperature that is barely necessary for expelling the moisture perfectly?

The management of the heat has been considerably misunderstood. It was known that, in kiln-drying, the colour of malt can be brought to any shade between the palest and the brownest, by peculiar management of the heat; and it was believed that the degree of heat is what decides the hue: now, however, it is ascertained that it is not the degree of heat, but the period of time employed to communicate this degree, that determines the colour. A heat of 175°, slowly applied, will leave the malt pale; while the same degree, quickly applied, will scorch it quite brown. Unacquaintance with this fact led Mr. Combrune into the mistake of supposing that, at this temperature, malt is blackened and burned; and the mistake led him into a variety of others.

From these statements, if they be all well founded, we learn that the saccharine matter separated from the malt, and in the insulated form, is readily decomposed by a low degree of heat; while, if it be allowed to remain in the malt, it is capable of sustaining that temperature without injury, provided it be slowly applied.

Another advantage to be derived from slow drying, is, that we, in this way, best expel the moisture. A quick heat will not only produce the bad effects already described, but it will harden the outside of the grain, and prevent the escape of moisture, while the hearts remain soft and starchy. Malt made in this way is liable to many objections: it may heat and take fire in the store; it may retain so much moisture that it will germinate anew, and send forth a full green acrospire; the centre of each grain being starchy, it will communicate to the drink a raw taste, or perhaps a musty flavour, and the drink will not keep sound. Beside this, such malt will soon give, and turn sour, or become ill fla-

voured, and will contaminate any good malt with which it may happen to be mixed in store. Malt that has suffered injury in consequence of having been originally badly dried will not be recovered by redrying it; and all these mischiefs will result as well from too quick a heat, which hardens the outside, and actually incarcerates the moisture, as from not continuing the heat long enough to dry it throughout, however well it may otherwise have been managed.

It is, therefore, inferrible, that we effect the greatest number of points by the application of a slow, long continued, well regulated, and low heat of the malt; and this observation applies, whether the resulting malt be intended for the pale, the amber, or the brown variety. A kiln of malt, to be advantageously dried, will require about twelve hours, although sometimes it is done in much less time.

The kiln used for drying amber malt is constructed as follows:—A furnace is built of masonry, with a wide short funnel. This funnel opens at top under a floor composed of sheet iron perforated with a vast number of very small holes; the holes are so close as almost to resemble a sieve. On this floor is spread the malt, and it is quickly dried by actual contact of the hot air from the burning fuel, which passes under and through the floor in all directions. The malt is parched until it has acquired a slight tinge of yellowness on the husk, but remains interiorly very near its original colour. It should barely retain a trace of sweetness, and this almost covered by the peculiar taste communicated by parching. The fuel used is frequently wood, but it is certainly objectionable; as during its combustion pyroligneous acid is generated, which may communicate acetic acid to the malt, and this may inoculate worts made from it with the acetous fermentation.

The deep brown malt, now in use under the name of *patent malt*, is made by roasting malt, and sometimes, fraudulently, barley, in an iron cylinder, in the same manner as coffee is roasted, until it become blackish brown,

By a heat intermediate between the degrees used for patent and amber malt, a peculiar acerb and acidulous flavour is produced, which is of consequence in some states of the public taste. By exposure to a brisk heat the malt is decomposed, and, like all other vegetable substances, it affords the pyroligneous acid during its decomposition. If the heat be skilfully managed, this acid may be *generated in* the malt without being expelled; and worts made from such malt will retain a certain sharpness or sourness, sometimes much valued in porter, when not too predominant. In this case, also, there is fear of inoculating worts made from such malt.

We are now enabled to appreciate the practice of maltsters with regard to the application of heat, — a practice that has not only been sanctioned but rendered necessary by the caprice of public taste. It is the custom to dry the malt with a heat so conducted, that three distinct shades of colour shall be produced, *pale*, *amber*, and *brown*. In the pale malt, the saccharine principle exists in perfection, and it affords the strongest and best beer. In the amber-coloured it is scorched, and therefore rendered less sweet, on account of the partial decomposition. In the brown, the scorching has proceeded so far, that scarcely any traces of sugar can be discovered. If it be very brown, the taste is even bitter and disagreeable. Hence we perceive that these varieties consist merely in the greater or less degree of charring which the sugar is made to undergo; and that the result is the greater or less destruction of the value of the malt, with what objects in view will be seen hereafter.

While the malt is on the kiln, it should be turned every three or four hours, so as to expose new surfaces to the heat, and to permit the free egress of watery vapour, which, at that temperature, is continually ready to escape. When it is judged to be thoroughly dry, the heat of the fire is lessened, and the malt is allowed to cool gradually. Meanwhile it is trampled, so as to detach the rootlets, which, being now dry and brittle, are easily broken. The rootlets are finally removed by a

fanning machine: the reason of removing them is, that they communicate an unpleasant taste to worts made from malt containing them. The malt is then spread out to *mellow*, that is, to lose its crispness, and to become soft and mealy,—changes attributable to the hygrometric absorption of moisture from the atmosphere during the exposure.* When malt has been thus mellowed by exposure, it is known to give out its saccharine matter to water infused on it with more facility than if used fresh from the kiln. This is consonant with reason: for if moisture be absorbed from the atmosphere, it is natural to suppose that the saccharine matter would be proportionately softened, and would dissolve away with more facility when acted on by water. But, perhaps, the change may be connected with a further development of sugar in the malt, by means of the water, in a way that will be explained hereafter. Even after the malt is ground in the mill, it is always allowed some days of exposure, but not in the sun. The more the malt has been kiln-dried, the more exposure it will require. Well-mellowed malt will permit the use of a hotter mashing water, on account of the cold water which it had already absorbed, a less time for mashing will be required, and consequently the risk of souring is so far diminished.

There have been a variety of opinions on the produce of finished and well-dried malt, estimated by measure and weight, derivable from a given quantity of barley. Some say that barley loses, by the process of malting, about one fifth; others say one fourth, including the spires: but Proust has affirmed that the loss is equal to one third. In the report of experiments made by direction of the Board of Excise in Scotland, in 1806, by Doctors Thomson, Hope, and Coventry, it is stated, as the result of many trials on a large scale, that the loss of weight was but eight per cent., including three per cent. of the comings; or the total loss was less than one twelfth of the whole. There is, however, a greater

* Dr. Thomson says, that the increase is but one-thousandth part.—*Papers presented to the House of Commons*, p. 60.

apparent loss; for the malt, when it leaves the kiln, is much drier than it was when in barley, and when first put down to steep. If the barley, about to be steeped, be previously kiln-dried, it will be found that 100 pounds of it lose about fourteen pounds of water, more or less. And if the fourteen pounds be added to the eight of real loss, the total loss would be twenty-two; but if the malt, when taken from the kiln, be exposed to the air for a sufficient time, it will be found to absorb from the atmosphere almost the whole of the lost fourteen pounds of moisture, which clearly manifests that eight pounds per cent. are the real loss.

As to the bulk or measure of malt, compared with the measure of the original barley, the same reporters state that, on an average, Scotch barley afforded the same measure of malt as there had been of barley: that 100 measures of English barley returned 105 of malt; and 100 of bere afforded 99. It is known that barley, gathered green, will not produce so much as its own bulk, be its quality in other respects ever so good.

It is now necessary to make some general remarks on the foregoing process, which would have come in with less effect under the respective stages; and, perhaps, the best mode of introducing the subject will be to describe the characteristics of good malt, which will afford opportunity of pointing out the consequences of defects in the process.

When malt has been prepared from a well selected barley, and has been rightly malted, it will present the following appearances:—Its grains should be large, clean, plump, and unshrivelled; its skin should be thin; it should be light, and specifically lighter than water. The acrospire should be seen to extend scarcely more than three quarters through the whole length of the husk. The grains should break without difficulty, and disclose a full, floury, mellow kernel, which, if drawn across a board, leaves a chalky trace. No part of the kernel should be hard or horny, as it often is at the end opposite the rootlet. The taste should be sweet and mel-

low, and should leave no impression of rawness on the palate. When broken between the teeth, it should feel soft and mealy. Being specifically lighter than water, it floats on it: if an unbroken grain sink partly or totally, it is an indication of being partly or totally unaltered from the nature of barley. The colour of good malt is pale and bright; it has no ill smell; and it is free from rootlets and dust. Its specific gravity, on an average, may be rated at 1·200. A bushel of good malt, when newly dried, weighs about three quarters of a bushel of the raw grain.

Malt that is shrivelled is not of the best quality: the cause of the defect is twofold. If the barley, from which the malt was made, was cut down while not yet ripe, there being a redundancy of juices, and a deficiency of farinaceous matter, the heat of the malt-kiln will contract the kernel in the husk, and the husk will be shrivelled, because not supported by a full kernel. Or if in the drying of the malt too sudden a heat be applied, the results will be the same.

Fraudulent dealers endeavour to remove the shrivelled appearance of ill made malt, and to imitate the plumpness of slowly dried grain, by the nefarious practice of sprinkling it, while warm from the kiln, with water. This, it is true, swells the grain, gives it an imposing appearance, and makes it tell better in the measurement. When malt which has been thus sprinkled remains some time in store, it grows soft, or *slack*, as it is called; it loses its sweetness, perhaps heats, becomes mouldy, and is soon totally spoiled. If drink be made from malt in even the first stage of this deterioration, it will soon sour if kept; and, even in the beginning, it has not the full flavour of what has been made from really good malt. When it is found that malt in store has *slacked*, the best remedy, although an insufficient one, is to redry it as speedily as may be.

Good malt, when first removed from the kiln, is always hard and crisp under the teeth, and remains so while ever it is at all warm. While warm, it cannot

mellow; but on cooling, it absorbs as much water from the atmosphere as causes mellowness: this it does slowly if it be whole, but rapidly if ground. But there is another kind of hardness which is to be guarded against; it is called *flintiness*, and is owing to the following cause:—the original barley might not have been long enough in steep to effect thorough penetration; or, being of mixed sizes, when the small grains were sufficiently steeped, the large ones were not penetrated. The unpenetrated grains would either refuse to germinate on the floor, or would germinate but little: and if the batch be then dried on the kiln, the grains that had germinated would produce saccharine malt; but those which had not would be found hard and gritty when chewed, and quite deficient of sweetness. When this *flinty* malt is exposed to the air, it does not absorb moisture, does not become mellow, but remains as hard as ever. Malt of this kind, even although mixed with some good malt, affords drink of a poor quality, and of a raw and ill flavour. And yet it is singular, that if actual raw barley be mixed with malt, and a brewing made from both, the drink is excellent,—a sufficient proof that half malting the barley is more injurious than not malting it at all. The reason that flinty malt produces bad drink is, that it contains very little saccharine matter, and that this little is locked up in a hard casing, which prevents the water from dissolving it away in the mashing.

Malt which has been under-dried, or, as it is called, slack-dried on the kiln, is as much injured as that which has been sprinkled with water, and is liable to the same train of ill consequences. Such should never be kept on hands; its only chance of affording tolerable beer is its being immediately used. Under-drying may be occasioned either by the application of heat during too short a period of time, or at too low a degree. Under-dried malt may be at once discovered by the adherence of the rootlets to the grain; for they have not been rendered crisp or brittle enough to be broken off during the tread-

ing. When these are seen adhering, it is certain that the malt will not keep sound.

Malt which has been over-dried will not absorb moisture from the atmosphere; hence it never mellows, and hence it resists the solvent power of the water during the mashing. Over-drying is the result of too high a temperature, or of a proper temperature too long continued. Too quick a heat of the kiln expels the water from the malt in the state of steam, with such force as to burst the grain. This is called *blown* malt.

Malt may be preserved good a whole year or more, if it have been carefully secluded from moisture. The higher stories of malt-stores are best adapted to the purpose. Long continued exposure to air is detrimental, although a little is found to be useful.

Barley is the grain from which malt is chiefly made; it is the best for malt, as it more readily germinates, and suffers the conversion of the starch into sugar more easily, but it is not superior in any other point of view. Bere makes excellent malt; and the drink made from it is light, sprightly, and pleasant. The produce from bere-malt is less, and therefore more of it must be used to obtain the required strength of liquor. If a barrel of barley-malt, mashed with a certain quantity of water, afford worts indicating fifty pounds' weight by the saccharometer, the same quantity of bere-malt and water will afford worts of perhaps only forty pounds' gravity. Bere has a strong, thick husk, which, in the grinding, must be well torn asunder.

Oats make an excellent malt, which, when mixed with barley-malt, in equal quantity, affords an excellent, mantling, sprightly, sweet drink. The same qualities will result from the mixture of raw oats well dried: but this practice is unfortunately prohibited by law.

Wheat also produces a fine malt, but does not afford as much sugar as malt from barley, nor so easily. Dried wheat mixed with barley-malt acts in the same manner as dried oats; the drink obtained from the mixture is excellent; but this practice is also contrary to law.

Millet and rice afford tolerable malt. The Chinese draw a spirit from the former of these grains, which, owing to their peculiar methods, has a taste like burnt brandy. *Arrack* is the produce of the latter grain. In order to produce malt from rice, the grain must be steeped a long time.

Rye produces a malt from which a very large quantity of spirit may be drawn; it is said to afford nearly one third more of spirit than barley-malt.

Maize, or Indian corn, may be converted into a good malt; but it will not succeed by the ordinary process. The following has been practised; and it is a method highly illustrative of the analogy which subsists between the natural germination of seed, when growing in the ground, and that which is artificially produced on the floors of the maltster. The clay, to the depth of two or three inches, being removed from the surface of a piece of land, the maize is sown so thick as to cover the ground, and the clay is replaced. As soon as the shoots appear, which will happen in ten or fourteen days, the ground assumes the appearance of a green field. The germinated grain is now to be taken up, and the clay shaken off. It will be mellow, floury, and very sweet; and the beer made from it will be wholesome and pleasant. This corn requires to shoot both ways, root and blade, to the length of a finger at least, or more, before it is properly malted. (*Philosophical Transactions*, abridged by Hutton, &c. ii. 469.)

Although a mixture of raw and malted corn will succeed well for making both ales and spirits, yet mere raw corn gives drink of a highly unpleasant taste: it does not keep sound; and the process is embarrassing.

Formerly it was the practice, instead of using the kiln for drying malt, to spread it out before the sun, which soon dried it, and left it perfectly pale in colour. The liquor made from such malt had not much more colour than water; whereas that made from kiln-dried malt has always a depth of colour which indicates a greater or less degree of decomposition by the fire.

A common method of giving the cleanness of well made malt to that which is poor and of a dirty colour, is to throw some sulphur into the fire under the kiln. The fumes of burning sulphur are well known to bleach straw and husks. Sulphureous coals have a similar effect. These practices are prejudicial to the fermentation of worts made from such malt: sulphureous acid is formed during the burning of sulphur, and this is a well known enemy to fermentation.

In the choice of fuel for the kiln some attention is required. In the bog districts of Ireland, the fuel made use of is turf: it imparts a singular flavour to the malt, which is still perceptible in the spirit distilled from it, and is by many persons much prized. A peculiar but disagreeable taste is given by wood, unless previously converted into charcoal: but coke has the double advantage of producing an even, steady temperature, so desirable in this process, and of communicating no flavour of any kind; it is therefore preferable when procurable. Further observations on the subject of kiln-drying malt will be made in the part of the brewing process which treats of *colouring matter.*

CHAP. V.

THEORY OF FERMENTATION.

SECTION I.

FERMENTATION IN GENERAL.—VINOUS FERMENTATION.—YEST.

THE ancient philosophers used the term *fermentation* in a vague and often unintelligible sense. It was intended to convey some mysterious, hypothetical, or latent process, more frequently than to express the exhibition of palpable chemical changes, such as the word is now understood to mean. In the modern acceptation, the word expresses the changes which vegetable or animal matters spontaneously undergo, and which terminate in the pro-

duction either of a vinous liquor, an acid liquor, or of a remarkable fetor.

Many chemists have considered these three different terminations as constituting three different kinds of fermentation. It is, however, more convenient to understand the whole series of changes as merely stages of one great process. And to this simple view it will be no objection to urge, that the last stage very often takes place without being preceded by any other; and that all the stages may be brought about separately. For, on the other hand, we have various instances in which they follow each other, not only in succession, but in an unvarying succession; the second following the first, and the third following the second; thus evincing consecutive stages. The following will serve as an illustration both of the process of fermentation and of its stages: but the subject will be resumed hereafter.

If some grape juice be left to itself, at the ordinary temperature of summer, it soon begins to suffer remarkable changes: the liquor becomes muddy; an internal motion takes place; the temperature perhaps rises; a bubbling noise is heard, owing to the breaking of minute air bubbles at the surface; and the whole appears not only to boil, but it tends to boil over. its bulk being swollen by the envelopment of so many air-bubbles. On account of this resemblance to boiling, the process is called *fermentation*, from *fervere*, to boil. Meanwhile a dense froth, composed of these bubbles involved in viscid matter, rises to the surface, and after remaining there some time, it parts with the involved air which floated it, and the viscid matter subsides to the bottom. At length the liquor remains tranquil, and soon after becomes transparent. The viscid matter possesses the property of exciting fermentation in certain other substances not spontaneously disposed to such a change, and hence it is called *ferment*, but commonly *yest* or *barm*.

At this period it is found that the grape-juice has lost its natural sweetness; the taste becomes strong, stimulating, and aromatic; and it acquires the singular pro-

perty of intoxicating, which it did not before possess. In short, it has become *vinous*, it is wine; and the whole series of phenomena constitute the *vinous fermentation.* An *ardent* or burning tasted spirit may be now extracted from the vinous liquor, and the ardent spirit, when very strong, is called by chemists *alcohol.*

After these changes, the fermented liquor being preserved for some time, corked in bottles if weak, or partially exposed to air if strong, and the temperature being maintained at about 75 degrees, a new set of phenomena will take place. Provided the quantity is large, a hissing noise is heard, and the temperature rises perhaps 10 or 15 degrees. A little gas is given out; the liquid exhibits an intestine but inconsiderable motion; floating shreds make their appearance, and at length partly subside and partly collect into a gelatinous cake which continually thickens. The liquor is now transparent; the vinous flavour and the alcohol have disappeared; and the taste has become extremely sour: in short, the wine is converted into vinegar, called in Latin *acetum;* and although the obvious symptoms of fermentation are inconsiderable, the process is called the *acetous* fermentation.

If vinegar be kept for a length of time, its surface becomes covered with a green mould which constantly increases; its acidity gradually disappears; its peculiar pungent acid smell gives place to a highly disagreeable odour; and, as this last effect proceeds from the rottenness (*putredo*) of the vegetable matter present, the whole change is called the *putrefactive* fermentation. All these stages of fermentation will be more fully detailed and explained hereafter.

Fermentations producing other results than these have been insisted on by some chemists. When flour is made into a paste or dough by means of water, and yeast added, as in the process of bread-making, the dough acquires sponginess, in consequence of being inflated in all parts by fixed air, or carbonic acid. It had been asserted, that dough in this state, if distilled, does not

afford alcohol, although it might have been expected to do so, if the fermentation which it obviously has undergone were the vinous. It was, therefore, concluded to be a fermentation essentially different; and from *panis*, bread, it was called the *panary* fermentation.

It was afterwards ascertained, that infusion of malt mixed with yest, although it certainly undergoes the vinous fermentation, will not afford alcohol, if distilled during the beginning of the process, any more than the dough.* But the question has been at length decided by the discovery of the fact, that fermented dough does actually afford alcohol when distilled; and that this would prove, on trial, to be the case had long before been supposed by Dr. Irvine. Hence there are no grounds for doubting the identity of the panary with the vinous fermentation; the former is the incipient stage of the latter; in the one, carbonic acid only is evolved; in the other, alcohol also.

Bodies in a state of complete dryness cannot be made to undergo any kind of fermentation. A certain quantity of moisture must be present in all cases; and where the fermentation concerned is the vinous, the body must be in a state of actual liquidity. A piece of meat containing all its natural juices will speedily putrefy; but if the water be expelled by drying, or rendered solid by freezing, the meat may be preserved for an almost unlimited period of time. A stiff dough made of flour and water, although containing so little of the latter, will soon turn sour, because it undergoes the acetous fermentation, and vinegar will be formed. Sugar will not ferment in any manner unless it be dissolved in as much water as will make it liquid; and then it is susceptible of the vinous fermentation; but not if the solution contain so little water as to constitute a syrup. In fact, the facility of exciting fermentation is in proportion to the dilution of the liquid. If the dilution be very great, the vinous stage commences, but is speedily followed by the acetous.

* Collier, Manchester Memoirs, v. 255.

A certain temperature is necessary to support fermentation of any kind: at 32° the vinous fermentation does not take place; at 50° it is languid; at 60° it is rapid; at 70° too rapid, and there is danger that the acetous stage will set in; at a degree much under boiling, it cannot exist or be excited. Thus a degree much above or much below a medium temperature is equally fatal to the process. Flesh will not putrefy at or near a boiling-water heat, nor at the freezing point. Wine and vinous liquids will not acetify at or near either of these degrees. Nor are solutions of sugar capable of undergoing the vinous fermentation, unless at a medium temperature.

There are substances called *ferments*, which possess the power of exciting the different kinds of fermentation in bodies. This is more obviously true in the case of the vinous fermentation; for bodies susceptible of that change do not undergo it, unless the proper ferment be present. Thus a solution of pure sugar in water will not decidedly ferment unless yest be added; nor will the juice of grapes or other fruits ferment, if they be deprived of a substance which they naturally contain analogous to yest. The acetous fermentation also is excited by its proper ferment; but this substance has never been obtained in a separate form. In many instances the vinous and acetous ferments seem to be modifications of the same thing. The matter deposited from vinegar is capable of acting as an acetous ferment; and there is a common practice, founded on this fact, of conducting the acetification of a saccharine solution in a vessel which had already served for making or holding vinegar. The putrefaction of flesh is so well known to be promoted by the proximity of flesh already putrid, that it need not be here insisted on; and the fact is not easily explicable, unless we admit the existence of some putrefactive ferment.

The question now occurs, What is the nature of the different ferments which produce these changes? No answer can be given to the question put in this general form, as the researches of chemists have been particu-

larly directed only to that one called *yest;* and this accordingly is the only one the nature of which is at all understood, and our knowledge of it is still extremely imperfect.

Yest has been variously represented by different chemists who investigated it. Fabroni considered it identical with *gluten.* This is a substance contained in wheaten flour, which imparts to it the property of forming a tough paste with water; and which may be separated from the flour by kneading a handful of it under water, until it no longer communicates whiteness to the liquid. What then remains in the hand is a grey, tenacious, tough, elastic mass, stretching out and collapsing again like Indian rubber. The white matter which has mixed with the water soon subsides; it is starch; and of this, along with the gluten, was the original flour composed.

This gluten, or some modification of it, is what Fabroni considered to be the true vinous ferment; and he supported his opinion by some striking facts, which have been added to by the researches of Thenard. It was found that solution of sugar, which by itself does not ferment, does so, although feebly, if some gluten be added, and much better if the gluten be dissolved, as by the addition of tartar. Without the presence of tartar, the juice of grapes refuses to ferment; and its effect is supposed to depend on its power of holding the natural ferment of the grape in solution. Gluten is not only contained in the different kinds of grain used for making fermented liquors, but also in different kinds of fruits, especially those which readily enter into spontaneous fermentation, as grapes and gooseberries. The juice of these fruits may be deprived of their yest by heating and filtering. What remains on the filter is a tasteless substance, insoluble in water, and decomposable by heat into the same ultimate elements as yest from grain. Grape juice deprived of its yest refused to ferment; but when its yest was restored, the juice fermented freely. Fruit yest added to solution of sugar caused an abundant fermentation; so also did wheat gluten in this solution, or in grape juice deprived of its natural yest.

If common yest or barm be allowed to stand for some time undisturbed in a tall vessel, a whitish curdy matter rises to the surface. This matter, if separated, will be found to be very active in exciting fermentation in saccharine liquors; at the same time the yest remaining in the vessel has lost that power. It therefore follows, that this curdy matter is the true ferment: it is found to partake very much of the nature of gluten; and seems to differ very little from the yest of the grapes, or of other fruits.

In some respects there are differences between the gluten of wheat flour and that obtained from yest, or from the juice of fruits: one of the most important is, that gluten of grain is much less efficacious in exciting fermentation than that of fruits. As a spontaneous fermentation takes place in the juice of grapes, gooseberries, apples, and various other fruits, as well as in worts drawn from the nutritive grains, although it is exceedingly feeble, it would be sufficient evidence of the existence in these fruits and grains of the principle which excites fermentation, be its name and nature what they may. And all the facts seem to prove that the gluten of wheat is either identical with, or a near approximation to, the nature of yest. Most probably the latter is the truth; and, perhaps, *ferment* is as much a proximate principle of vegetables as sugar or starch, and extensively diffused throughout nature.

Seguin, however, has endeavoured to prove that the true fermenting principle is *albumen*, which he found to exist in all those vegetables, the juice of which readily runs into decomposition. He even affirmed that animal albumen, as the white of egg, is capable of exciting fermentation, — a fact which Fabroni had denied. The opinion of Seguin seems to be ill supported.

The yest of beer kept for some days in a close vessel, and at the temperature of 70° to 90°, undergoes the putrefactive fermentation. If the contact of oxygen be allowed, that gas is converted into carbonic acid, while probably a little water is also formed. Hence the

yest affords carbon, and perhaps a little hydrogen, to the oxygen. The grounds of the latter supposition are, that the volume of carbonic acid is somewhat less than that of the original oxygen. When the yest is pressed, so as to separate the chief quantity of water, and exposed to a gentle heat, it dries into a hard granular substance which retains all the original properties for a great length of time. It may be preserved much longer by dipping twigs in it and drying them in the air. By drying it is reduced to one third of its weight. By maceration for some time in boiling water its fermentable powers are either greatly diminished or destroyed. (Thenard.)

The kind of yest to be made use of for inoculating wort is by no means a matter of indifference. This substance seems sometimes to inherit the character of the parent stock from which it was derived. Thus strong ales ferment slowly, and with a kind of persevering, although suppressed, energy. Yest obtained from such excites an energetic fermentation in any wort with which it is employed. Weak beers ferment feebly, although rapidly; soon arriving at their greatest height, and soon ceasing to work. The yest afforded, in such cases, is quite unfit for strong drinks, as it is incapable of producing a powerful fermentation in strong wort.

Sometimes it is found that the yest successively generated in a brewery will not always maintain itself in good condition, but will degenerate after successive brewings, and will at length fail: just as potato crops are deteriorated when they are several times reproduced from their own seed. In such cases, the remedy is to introduce yest from some other brewery, taking care that it is collected from a healthy fermentation.

New yest is by far more active than old; and in apportioning the quantity to be used for a brewing its age must be taken into account: it must be increased sometimes to twice or thrice what would have answered of new active yest. But quantity will never fully compensate for quality: bad yest, used in large quantities,

always communicates something unpleasant to the taste, and this is particularly the case in the process of the distiller. Yest so far resembles animal matter, that it is extremely liable to putrescency. This must be carefully watched: for a very small quantity of putrid yest will, as is well known, spread contagion throughout a whole tun of fermenting worts.

The quantity of yest to be employed should always be determined by weight, as the same bulk may consist of more or less real yest, inflated more or less with carbonic acid.

Part of the total quantity of yest generated in any brewing rises to the top of the tun in the state of a close, yellowish, dense, tough froth. This is the best kind, and it should be collected just when it assumes this dense tough appearance, which happens only when the fermentation is tolerably far advanced. That which rises first on the tun, and forms what is called *rock-work*, is not by any means so active: it will fall back into liquid if set by. The yest which falls to the bottom of the wort, after the fermentation is far advanced, is never to be used when the former is procurable; it is comparatively feeble.

The distiller does not save yest from his fermenting tun, but uses it fresh from the brewer, as required. His attenuation requires to be urged as low as the nature of things permits, in order that he may procure the utmost quantity of alcohol, which is his sole object. He therefore beats down the head of yest, so as to diffuse it through the whole volume of wash, and thus to keep up the fermentation when it languishes.

When yest first begins to be thrown up on the surface of brewers' wort, it is white and creamy. After some time it becomes more deeply coloured; and on the very surface may be observed a still more deeply coloured curdy matter, which contains all the rough intense bitter of the hop. This should not be allowed to return into the liquor: it should be skimmed off, and might be turned to use if its nature were properly investigated. In certain locali-

ties the public taste does not permit the rough bitter to be removed by skimming off the head; there cannot be, therefore, any unvarying rule laid down.

According to Combrune, the worts produced from eight bushels of malt afford, by fermentation, but two gallons of yest. But it may be obtained much more economically by various processes which afford it at a low price, although by no means of as good a quality. Westrumb gives the following: — Two pounds of wheaten flour are to be made into a thick paste with cold water, then water heated to 180° is to be added, and worked into a paste until the whole assume the consistence of yest. The mixture is to be allowed to cool down to 75° or 85°; two pounds of beer yest are to be added, and the mixture is to stand in a place of the same temperature. It soon ferments; and when at the greatest height it is fit for use.

Another process is as follows:—Take finely-ground rye or wheaten meal, and, without separating the bran, knead it with cold water so as to form a thick paste. To this add quarter the weight of the meal of molasses or honey. Dilute with boiling water until the whole is of the consistence of pap, and its temperature about 85°; and add yest or bakers' leaven. The vessel being covered is to be maintained at the temperature of about 80°. The fermentation ought to be established in an hour; but if not, add more yest. When the fermentation is at its greatest height, it is fit for use, and it ought to be used before it is sour. In general, it is perfect in twelve hours. This, as a ferment, is greatly superior to leaven; and has the advantage of yest in not giving an ill flavour to the products of fermentation when used in excess.

A ferment or leaven for the use of the baker may be made by setting aside some paste of wheaten flour and water until it become sourish. At the temperature of 85°, twenty-four or forty-eight hours will be sufficient. For the use of the distiller, five or six days will be required: in that period it acquires a much greater power of exciting fermentation. But it is greatly inferior to

yest, as it is apt to excite sourness in liquors, and injures the vinous fermentation. It may be preserved for a month, by covering its surface with salt, and including it in a vessel.*

A yest which answers for baking may also be made from potatoes in the following manner: — Boil some potatoes, which have no traces of decay, and are free from worm-holes, until they are perfectly soft and just beginning to break into meal. They are to be reduced to a very thin paste with boiling water. One eighth the weight of potatoes is to be added of molasses, and about the same bulk as the molasses of good yest; all are to be well mixed and placed before the fire, if in winter. The mixture soon begins to ferment, and when the fermentation is at its greatest height it is fit for use.

The chief use of yest is for raising bread, and exciting fermentation in malt infusions for brewers, distillers, and vinegar makers. It is used in medicine as an antiseptic, internally and externally. It was used by the Romans for making bread light and spongy; and by the Roman ladies as a cosmetic.

Having thus considered the nature of the ferment, the next point to be determined is the nature of fermentable substances, and whether or not there is any particular kind of matter on which ferments exert their action peculiarly. On these questions there have been various opinions.

It had been observed that sugar in solution and other saccharine liquids are the most easily made to undergo the vinous fermentation; that the fermentation so produced is the most active and rapid of all others; and that the most saccharine liquid produces the most alcoholic wine. It was even observed that all the liquids which ferment well are invariably saccharine; and, as observations were extended, it was an opinion admitted by chemists, that no other than saccharine solutions can be made to undergo the vinous fermentation. A secret practice of the distillers, which at length came to light,

* Dubrunfaut.

appeared for a while to oppose the admission of this as a general principle. It was found that a mixture of raw corn with that which has been malted is capable of fermenting as well and of affording even more alcohol than if the whole corn had been malted. This fact was first distinctly noticed by Dr. Irvine, who conceived that the farinaceous or starchy part of grain may be converted into saccharine matter, and from that into alcohol, merely by the action of common sugar, or of the saccharine matter produced in grain by malting; thus proving, as he conceived, that the formation of sugar in the seed is not always dependent on the functions of vegetable life during germination. The proof of this, according to Dr. Irvine, is, that if solution of saccharine matter be made to undergo fermentation, whether vinous or acetous, it will produce either alcohol or vinegar, the quantity of which will be much increased if the meal of raw corn had been previously infused in the saccharine solution; and during the process the raw corn will contribute additional sweetness. Now raw corn by itself, says Dr. Irvine, would not have evolved any alcohol, and would have afforded but little vinegar; hence its nature must have been altered by some action produced on it by the ready formed sugar.

The facts stated by Dr. Irvine are now well known to be true; but there is reason to think that they may be explained otherwise than he has done, and that such explanation is better supported by what is known. Late researches have shown that sugar may be generated from the starch of grain in a variety of ways, and by agents actually present in the grain itself. Kirchoff ascertained the important fact, that if pure gluten from wheaten flour and starch from potatoes be mixed in hot water, and allowed to act on each other, the starch is converted into sugar. Neither gluten nor starch, separately acted on by hot water, became sweet; and as the gluten appeared scarcely changed in its nature, it is plain that the sugar resulted from the starch, in consequence of some unknown agency of the gluten. In the case ex-

plained by Dr. Irvine, there are both gluten and starch concerned, both being contained in raw corn ; and when this is mashed with hot water, the starch will be converted into sugar, whether there was any malted corn to supply ready formed sugar or not. Hence the starch of the raw corn may be converted into sugar, not by other sugar, but by gluten ; and hence Dr. Irvine's explanation, although it may or may not be true, is so far unsupported by any experiment of exclusive import.

There are, however, some experiments of M. Clement which might appear to decide Dr. Irvine's opinion in the negative, and to prove that other substances beside sugar undergo the vinous fermentation ; but their evidence may be set aside by facts already adduced. M. Clement shows, that by mashing and fermenting rye meal an alcoholic liquor is produced, although the grain had not been malted ; and that equal quantities of the raw grain and malted grain, separately mashed, afforded equal quantities of alcohol. He further states, that alcohol may be abundantly obtained from potatoes, without any other preparation than boiling them in steam, breaking them down into a fine paste with water, and adding a little raw flour and some yest. A fermentation is excited ; and if the liquid be distilled, it affords, after some hours, alcohol in remunerating quantity.*

By these and other researches† of a similar tendency, it has been supposed to be proved that starch may at once be converted into alcohol, without having passed through the intermediate state of sugar. But in the cases alluded to there was a quantity of gluten present, derived from flour, or yest, or both ; and we know that a very small quantity of this substance acting on starch is sufficient to convert the latter into sugar, in the manner ascertained by Kirchoff. This sugar, as soon as formed, might have rapidly and successively passed through the vinous fermentation into alcohol. We know that so trivial a cause as exposure to cold determines the conversion of potato-starch into sugar, as appears from the

* An. de Ch. et de Ph. v. 422. † Ibid. xiii. 288.

sweet taste of potatoes after frost. In short, from a knowledge of Kirchoff's experiment, all these results might easily have been anticipated; the gluten of the rye in one case, and of the yest or flour in the other, being the agent. But Dr. Irvine's opinion remains unaffected by any of them.

It may be here remarked, that the process for obtaining alcohol from potatoes is by no means new. In the Swedish Transactions, quoted by Dr. Lewis (on Neuman), there are some experiments made by Mr. Skytte. Sixteen measures of potatoes were boiled with water, and worked with the liquor, till the whole became a tough dough. This was diluted with boiling water to the consistence of gruel, and fermented. The liquor, distilled on the third day, yielded one measure of good brandy. He concludes, that the produce of spirit from potatoes is to that from barley, in equal extents of ground, as 566 to 156; the potato ground being very bad, and the barley ground very good.

From all the statements adduced it therefore appears, that the opinion of chemists as to the nature of the proper subject of the vinous fermentation is not contradicted by any known fact. It appears that sugar, or at least some saccharine matter as we call the modifications of sugar, is the only substance which supports the process in question; and that where sugar is not palpably present, its elements are, as also some substance which is the instrument by which they are arranged in such a way as to produce sugar. It may be converted into alcohol as soon as formed, and may thus escape detection *in transitu*. In seasons when, the corn being very nearly ripe, there are considerable falls of rain, the ears are bowed down to the earth; the grain is actually steeped in water, and a commencement of germination takes place. The grain is then said to be malted; that is, it has commenced the growing process, just as if it had been sown in the earth. This being checked, it can never grow again, and therefore cannot be malted further. Such corn may, in this state, be unfit for any purpose;

it is too little malted for the purposes of fermentation, and too much altered for any other use. This would be an irremediable calamity, but for the fact already described. Such corn is, notwithstanding, as fit for fermentation as malt itself; for, during the malting, the starch remaining unchanged, is converted into sugar, by the sugar already formed, as Dr. Irvine says, according to the experiment of Kirchoff already detailed, or by the gluten of the grain.

But although sugar thus appears to be the proper subject of the vinous fermentation, we are not to infer that if sugar is present it must necessarily be possible to induce fermentation on it. On the contrary, we are acquainted with one kind of sugar, namely *manna*, which, when purified from some common sugar which it naturally contains, seems incapable of undergoing fermentation; at least chemists have not succeeded in inducing it; and there may be other kinds of sugar which refuse in the same manner.

There is one other condition, essential to a successful fermentation, which naturally flows from those already noticed, and which has been previously adverted to under different heads. This condition is the proportion of all the ingredients concerned in the vinous fermentation. If there be too much sugar compared with the water, the process is impeded in two ways, according as the excess is great or very great. If very great, the liquor is not sufficiently diluted to allow freedom of motion to the acting particles; they are entangled, and their agency is obstructed in the same way as we know other energetic agencies to be by viscidity. If the excess be not very great, the impediment to the process of fermentation arises from the too abundant formation of alcohol, which, when concentrated, impedes the fermentation of all bodies. The quantity of alcohol formed is proportionate to the quantity of sugar which actually undergoes fermentation; and hence, if there be too much sugar in the act of fermenting, there will be too much alcohol formed for the continu-

ance of the process, and it must at length cease, the sugar being actually preserved from further change by the abundance of alcohol. Thus, a very great excess of sugar prevents the fermentation from taking place at all, and a more limited excess checks the process before it has been completed. Too little sugar, or what is the same thing, too much water, produces proportionately little alcohol; and the presence of that little, far from preserving the liquor from further change, promotes its transition to a new stage, as will be hereafter seen.

The ratio of the yest is equally important: if there be too much, and the temperature be high, the vinous fermentation can scarcely be prevented from running into the acetous. If there be too much at a low temperature, the fermentation is languid, and the liquor acquires a sickly taste, which it ever after retains. An effect not very different from this last follows from the use of too little yest at a high temperature.

From all that has been said, it now appears that there are several conditions essential to the production of the vinous fermentation; they may be summed up as follows:—

1. There must be water present, and in such ratio as produces moderate dilution.
2. There must be a moderate temperature; the process does not go on at either the freezing or boiling point of water; at summer heat it is most active.
3. There must be a substance called a *ferment* present to commence the process; and once commenced, it will go on without the presence of the ferment.
4. Besides the ferment there must be fermentable matter, that is, sugar, or some modification of it; and this is the subject-matter on which the change is effected, and which gives rise to the new products.

During the vinous fermentation an immense quantity of carbonic acid gas is generated, and escapes by effervescence. Alcohol is at the same time gradually produced, and remains mixed in the liquor. The taste of the liquor

becomes less sweet, and when the formation of alcohol is complete, the sweetness has totally disappeared. In short, the sugar is decomposed; and the only products found resulting from it are carbonic acid and alcohol. Such, then, is the whole of what takes place during the vinous fermentation; for so small a quantity of yest is decomposed in the process that the consideration of it may be wholly neglected. For every hundred parts of sugar that disappear, only one and a half of yest is decomposed. The water suffers no change. Sugar is composed of three elements, carbon, hydrogen, and oxygen. The following are the respective quantities in 100 parts by weight:—

Carbon - -	42·47
Hydrogen - - -	7·19
Oxygen - -	50·34
	100

The hydrogen is just one seventh of the weight of the oxygen; therefore these two elements are in the proportions which constitute water. During fermentation the combination is subverted: one hundred parts of sugar afford, while fermenting, 48·66 of carbonic acid, which are composed of 13·26 parts of carbon, united with 35·40 of oxygen. Thus, of the whole 42·47 parts of carbon present in 100 parts of sugar, 13·26 go to the formation of carbonic acid, and there remain 29·21 of carbon to form the basis of the alcohol. Of the whole 50·34 parts of oxygen there remain 14·94, which also enter into the composition; and the whole hydrogen combining with these two elements, the result is the sum of their weights, amounting to 51·34 parts by weight of alcohol; which weight, added to that of the carbonic acid (48·66), gives 100, the quantity of the original sugar decomposed.

It is to be observed, that besides carbonic acid, hydrogen gas is, under certain circumstances, extricated during fermentation. Fourcroy and Vauquelin observed the production of this gas from barley-malt worts fer-

menting at 80° without yest.* And Proust affirms that azote is also emitted. In the fermentation of potato-starch syrup, inflammable gas is often generated: in such cases the fermentation goes on badly, and affords but little alcohol. Perhaps putrefaction has commenced in these instances.†

The changes which take place during the vinous fermentation may be thus briefly expressed:—Some of the carbon and some of the oxygen combine to form carbonic acid; while the remainder of the carbon, the remainder of the oxygen, and the whole of the hydrogen, combine to form alcohol; and we may totally neglect the decomposition of the yest, it amounting to almost nothing. Thus is this inert, solid, fixed, sweet matter resolved by a new arrangement of its principles into substances which possess none of these properties, and one of which exerts a control of so singular a nature over the animal economy.

The manner in which the decomposition is effected is difficult to understand. Yest is admitted to be the agent; but chemists are not agreed as to the nature of its agency. Gay Lussac is of opinion that the vinous fermentation is merely the change produced on sugar by the operation of a new order of affinities, its consequent decomposition, and the formation of new products by a different arrangement of the old elements. Thenard conceives that the change is commenced by the interposition of the affinity of the elements of the yest amongst those of the sugar; for yest is known to possess a powerful affinity for oxygen. The carbon and hydrogen of the yest combine with portions of oxygen from the sugar, at least during the first stages of the process. The equilibrium of affinity between the constituent elements of the sugar being now subverted, these elements react on each other, and combine in such a manner as to transform themselves into alcohol and carbonic acid. The yest, therefore, merely commences the process by taking a minute quantity of oxygen from

* Phil. Mag. xxv. 224. † Dubrunfaut, Traité de l'Art de la Dist. i. 263.

the sugar: the equilibrium of affinity in the sugar is thus altered, and the rest of the changes go on independently of any agency of the yest. The products formed by the union of the principles of the ferment with the oxygen of the sugar are so small, that they may be considered as almost nothing, and may be neglected in any calculations. Thenard supposes that nitrogen enters into the composition of alcohol: for he ascertained that nitrogen exists in yest; that it is abstracted from the yest which has served for fermentation, on which account it will not excite fermentation more than a second time; and that it is not found in the carbonic acid evolved, although the contrary is asserted by Proust. Hence Thenard concludes that it must exist in the alcohol, although analysis failed to detect it; and this failure leads us to suspect that the statement of Proust is well founded. T. Saussure, at one time, admitted nitrogen amongst the principles of alcohol; but in his last memoir he states it to be composed of hydrogen, oxygen, and carbon.

Fabroni had suggested a theory nearly similar to that of Thenard. He supposed the whole quantity of carbonic acid produced to result from the combination of the carbon of the yest with oxygen from the sugar, the remainder of the elements then all combining together to form alcohol. Seguin supposed the carbon of the yest to derive the necessary supply of oxygen, for the formation of carbonic acid, from the water constituting the solution, its hydrogen uniting with the elements of the sugar, and thus forming alcohol. Lavoisier inferred, that from the sugar alone we derive the total quantities of carbonic acid and alcohol which appear during fermentation, one part of its carbon being combined with some of its oxygen, so as to form carbonic acid, and the remainder of the oxygen and carbon combining with the whole hydrogen to form alcohol. None of these theories seem satisfactory, and much yet remains to be done before we can consider the theory of fermentation as understood.

Since, during the distillation of fermented liquors, alcohol is the invariable product, it would seem a natural inference that the alcohol had previously existed as such in the fermented liquor. Yet this inference was called in question by Fabroni, who concluded that the alcohol did not previously exist as such, but was *generated* from its elements, by a decomposition produced by the heat to which the liquor is exposed during distillation. This opinion was subverted, and the original one established, by experiments in which alcohol was obtained from fermented liquors that had never been exposed to heat. These experiments were made by M. Gay Lussac, Mr. Brande, and myself.

It is now necessary to state some of the conditions under which fermentation may be conducted, and the effects produced by them.

The changes which take place during this kind of decomposition are totally independent of the chemical agency of the atmosphere; but they are considerably influenced by its mechanical agency. Fermentation will take place in close vessels, or in vessels which have a free communication with the air. If there is perfect facility of escape for the carbonic acid gas evolved, the fermentation proceeds with freedom: if the vessel is close on all sides, except where a tube enters it, the far end of which is immersed in water, the carbonic acid escapes through this; but there is pressure on the fermenting liquor equal to the depth to which the tube is immersed, and the fermentation is rendered proportionately slow. If the liquor is contained in a perfectly close vessel, as in the case of a well-corked bottle, the fermentation still takes place as effectually, *at length*, as in any other case; but the process is very slow. There is every reason to believe that if the pressure of the atmosphere were removed, or if it were increased, the chemical changes would be accelerated or retarded; and, in short, the mechanical pressure of the atmosphere, or of any gas, acts as an antagonist to the decomposition.

When the conditions are such that the fermentation

proceeds rapidly, and that there is consequently free egress for the evolved gas, there is a waste of some of the more valuable products, and the resulting liquor is less generous and less alcoholic; for there is evidence that some of the alcohol escapes along with the carbonic acid. It was found by M. Goste, that grapes which had been exposed to the vapours issuing from a fermenting tun of wine acquired such a taste of alcohol that they resembled grapes preserved in brandy; and it is known to be possible to convert the matter which escapes with the carbonic acid altogether into vinegar. Chaptal effected it by causing water to absorb the gas emitted, and exposing it for a length of time in open vessels. Mr. Collier found, by comparative trials, that close vessels always afford more alcoholic worts than open ones.* The best mode of preserving the strength of a fermenting liquor is to conduct the process in a vessel into which the atmosphere cannot enter, yet from which the carbonic acid can freely escape; as through a wide tube, having its other end immersed one or two inches in water: such an arrangement, beside adding to the strength of the wort, lessens the risk of its souring.

In some cases, however, access of air must be admitted, at least for a short time, at the commencement of the fermentation. Gay Lussac could not cause grape juice to ferment when the air was completely excluded, although solution of sugar mixed with yest did so easily under the same circumstances. On admitting some oxygen to the grape juice the gas was absorbed; and then a fermentation commenced, which continued independently of further contact of oxygen. By boiling grape juice for a short time, and secluding it from contact of air, it may be preserved without fermenting; but as soon as communication of the air is allowed, oxygen is absorbed, and the liquor ferments. As solution of sugar with yest of beer does not require access of air during any period of the process, Gay Lussac inferred that the yest of beer is different from the yest of grape,

* Manchester Memoirs, v. 258.

which at first requires a little oxygen to commence the fermentation.

The quantity of a fermenting liquor has a considerable and important effect on fermentation: the activity of the process is in proportion to the quantity operated upon. M. Duportal observes, "M. Chaptal has seen *must* (grape juice), contained in a cask, not finish its fermentation until the eleventh day; while a large tub, which contained twelve times the quantity, has completely fermented in four days. The heat of the liquor in the cask never exceeded 74°, while that in the large tub reached 94°. It will readily be conceived that the wine in the cask could not be so good as that in the large vessel; that the combination of the principles of the must could not be so perfect. However, a very large tub has one disadvantage: as the heat produced is so much greater, there is a greater volatilisation of the alcohol and aroma, upon which the goodness of the wine so much depends."

When yest has been added to a saccharine solution, the fermentation is not observed to commence immediately. But very shortly after, if the temperature be sufficient, very small air-bubbles may be perceived forming in the bottom, and these become a little larger as they rise to the surface. But it does not follow from this that the fermentation did not really commence immediately: it would appear more probable that it did, inasmuch as all the conditions were present, at first, as well as at any subsequent period. The truth in all probability is that the formation of carbonic acid gas took place immediately; that as fast as formed it was absorbed by the liquid, and held dissolved; and that no effervescence became visible until the liquid was saturated, which it would soon be where sugar was also held in solution.

As during fermentation, the heavy saccharine matter gives place to the production of so light a fluid as alcohol, the specific gravity of the fermented liquor is continually lessening as the process approaches completion. From being much heavier than water, the liquor

becomes sometimes even lighter, and this lightness is made use of as a criterion to judge of the completion of the fermentation.

Section II.

ACETOUS FERMENTATION.

The phenomena of the acetous fermentation have already been alluded to. If a liquid which has undergone the vinous fermentation, and which has not been depurated from all glutinous or mucilaginous matter, be left to itself for a length of time, protected from contact of air, or for a shorter time, if partially exposed to air, and if the temperature be maintained to about 70° or 75°, not higher than 80°, nor lower than 40°, a new set of changes will take place. Provided that the quantity is large, a hissing noise is heard, and the temperature rises a little, perhaps 10 or 15 degrees. If the contact of the atmosphere is permitted, a little carbonic acid is given out, and some is absorbed by the liquor, the total quantity being about twice the volume of the whole liquor concerned. This carbonic acid is produced in consequence of the abstraction of oxygen by the carbonaceous matter present in the liquor; the oxygen being supplied by the common air present. But the oxygen does no more than abstract carbon, it does not enter into the composition of the vinegar. Acetification may, however, take place when there is no atmospheric air present. This happens in the case of bottled beers, cider, and weak wines; and in some other instances of a more striking and decisive character. In such, the fermentation is not accompanied by obvious symptoms, and the changes which take place are not well understood. Strong wines and similar strong liquors acetify with great difficulty, unless contact of air be allowed; hence bottled strong wines do not become sour. Nor will good vinegar be obtained if access of air be too

freely permitted, for acetic vapours are in that case abundantly carried off.

The liquid during the acetous fermentation exhibits an intestine, but inconsiderable, motion; little gas is extricated, and the process is comparatively quiet. Floating glutinous shreds make their appearance, which, after a long time, subside into a gelatinous deposit. In some weeks, the liquor has become transparent; the vinous flavour and the alcohol have disappeared, the liquor has become very sour, and has acquired a pungent smell. It is now converted into *vinegar*, and it is not homogeneous in its nature, being a compound of a powerful corrosive, and inflammable acid, called the *acetic acid*, with a considerable quantity of water and vegetable matter. According to Chaptal, if the acetifying process has been complete, the alcohol completely disappears. If malic acid had been present, as it generally is, it also will frequently disappear with the alcohol; but in common vinegar the change is never so complete that a little malic acid and alcohol will not be found unaltered. The conversion from the vinous to the acetous state takes place in dilute liquors with great facility, and often the two states are not consecutive but simultaneous. In the fermentation of infusion of malt on the large scale, as conducted in distilleries and breweries, the greatest caution, in moderating the fermentation and temperature, will often fail in arresting the tendency to acetification. On the small scale it is easily prevented.

The question occurs, what becomes of the alcohol, the most remarkable ingredient of the original vinous liquor, when the latter is changed into vinegar? The answer is, it has been decomposed; its elements have been separated, and have combined again in new proportions. This might appear surprising, considering the apparently indestructible nature of alcohol. Its nature is certainly imperishable while it is concentrated; but when diluted with water, and mixed with vegetable matter, which easily undergoes fermentation, such as gluten, starch, sugar, or mucilage, they are all resolved by the acetous

fermentation into vinegar. Upon this subject there is some difference of opinion. Chaptal states that wine which had been depurated from vegeto-animal matter by age did not turn sour when exposed to the summer heat of a warm climate for forty days, although the bottles were open. Such wines, instead of souring, merely lose their colour, acquire an acerb taste, and do not recover the property of passing into the acetous fermentation unless we digest vine twigs or leaves, or a bunch of grapes, or yest in them, and then they will sour in a few days. M. Heber of Berlin, on the other hand, affirms, that if a mixture of seventy-two parts of water and four of pure spirit be exposed to a heat of about 80° for two months, the result will be vinegar. This is denied by M. Resal, who states, that under such circumstances no vinegar will be formed unless charcoal be added. It is certain that where vinegar is formed it is produced the more readily, but less abundantly, the greater the ratio of water to the alcohol had been; and this holds true equally in the case of wines, ales, or fermented liquors derived from solutions of common sugar. Strong foreign wines afford a stronger and purer vinegar than any other fermented liquor can supply. But if they have been clarified they will keep almost any length of time without souring.

Vinegar is economically obtained from the fermented juices of all fruits, from solutions of sugar, whether derived from malted grain or other sources. It may be procured, although less abundantly, from infusions of various roots, even those which do not taste sweet, and are actually insipid, as the dried sarsaparilla root. The water from which starch on its first extraction has been deposited also changes into weak vinegar, owing to the presence of both gluten and starch, the mutual action of which, under certain circumstances, evolves this acid, as Berthollet has shown. Solution of gum very soon acetifies. But of all other sources, vinegar is obtained most abundantly and economically in the distillation of wood, by a process to be detailed hereafter. Certain vegetable

substances, on being distilled with sulphuric acid, furnish vinegar.

It is to be observed, that in all cases of the formation of vinegar, whether it be produced from fermented solutions of sugar, infusions of malt, or from wines, the greater the quantity of alcohol which existed in the liquor the stronger will be the vinegar obtained, and the more difficult and slow will be its formation. But from this we are not to infer that alcohol is the only ingredient capable of affording vinegar. We know that other matter which the vinous liquor contained, previously to its acetification, is not found after that process: this has in all probability contributed to the quantity of vinegar. It has been already mentioned that wines acetify difficultly in proportion as they are strong; and that the existence of natural sugar or mucilage in them imparts facility of souring. Adding sugar during the souring increases the quantity of acetic acid.

All vinegars prepared by fermentation contain the following ingredients:—Much water, a little alcohol, some malic acid, a small quantity of sugar, some glutinous and mucilaginous matter, with what is vaguely called extractive matter, beside acetic acid. Vinegar from malt or sugar contains more glutinous and mucilaginous matter than that obtained from wine: hence it is less desirable where purity is required. But either kind of vinegar may be considerably freed from these impurities by boiling it: the heat coagulates the foreign matter contained in it, and on cooling, this may be separated by straining. Vinegar prepared in this manner keeps longer without spoiling; and hence the necessity of boiling vinegar, cooling, and straining, when it is intended for pickling vegetables. This useful and simple process is the invention of Scheele. His 20th essay is devoted to the subject; and as it contains a vast deal of information condensed into a small compass, it is here subjoined:—

"It is a fact generally known, that vinegar, of whatever kind, will not keep long; but, in the course of a few weeks, especially in the warm temperature of sum-

mer, grows turbid; and that its surface is covered with a thick mucilaginous substance; during which period the acid disappears by degrees, and at last is entirely lost; whence the vinegar must very often be thrown away. Now, in order to avoid this corruption of the vinegar, five methods have been discovered. The first is, to prepare the vinegar very strong and sour at first. It is well known that such vinegar keeps for several years; but as there are few people who prepare their own vinegar, and as most persons content themselves with buying it as it is to be had in the shops, there are of course but few who can make use of this method. The second method is, to concentrate the vinegar by congelation; after which a hole is made in the crust of ice which covers it, through which the part that is not congealed is let out, and afterwards put into bottles. This manipulation answers well enough; but nearly one half being lost, because that which forms the crust of ice is nothing, for the most part, but water, good economists dislike it. The third method is to prevent the access of air, viz. to fill the bottles full, and keep them perfectly well corked. Though vinegar by this method keeps very long, it is not much employed; probably because it is troublesome to fill the bottle immediately again with clear vinegar from another bottle every time you have made use of part of its contents; after which, the vinegar in the bottle that is not full, and to which, consequently, the air has access, soon grows turbid and vapid. The fourth method is to distil the vinegar: such vinegar suffers not the least change, though exposed to a warm air for years; but, being more expensive than that which is not distilled, this method is seldom made use of, especially as the following method to preserve vinegar is the easiest of all:—

"It is only necessary to put your vinegar into a well-tinned kettle, and make it boil for a quarter of a minute over a strong fire. It is then to be immediately bottled carefully; or if any one should be afraid of tin being pernicious to health, he may fill his bottles first, and

then put them into a kettle full of water upon the fire. After the water has boiled for about an hour, the bottles are taken out of the pot and corked. The vinegar thus boiled keeps for several years, as well in open air as in half-filled bottles, without growing turbid or mucilaginous. It likewise may be used with advantage for pharmaceutical purposes, instead of common vinegar; for the preparation of the compound vinegars, which, if not prepared with distilled vinegar, soon grow turbid, and lose their acidity."

That process called *mothering* in vinegar is the commencement of putrefaction: it is owing to the foreign vegetable matter present, and takes place more or less speedily as this matter is more or less abundant. Vauquelin conceives that of all the different foreign matters present, the vegetable gluten is the one which promotes this change. Hence the importance of its removal. Distillation of vinegar affords it nearly but not entirely pure, the foreign matter remaining almost fixed, although a little is elevated. The glutinous scum which forms on the surface of vinegar will by drying shrink from the thickness of a quarter of an inch to the thinness of gold-beater's leaf, which it then resembles in transparency, thinness, and toughness. Vinegar will spoil even in glass vessels hermetically sealed. Boerhaave alludes to an experiment in which the vinegar remained thus enclosed for four years, and at the end of that time it was found to be insipid, and to have acquired an aromatic odour.

In France vinegar is made by exposing weak wines to the conjoint action of air and warmth. Wine vinegar holds malic and citric acids, together with some impure tartar dissolved; it is, however, the purest kind: it contains much less mucilaginous matter, and more alcohol: the average quantity of the latter is about one sixtieth measure.

Vinegar is always more or less coloured: its tint when tolerably pure is yellow; but when less so, it is darker and even brown. M. Figuier states that red

vinegars may be deprived of their colour by mere agitation with a small quantity of animal charcoal, prepared by the calcination of dense bones in crucibles, at a high heat; the air being kept off during the calcination by filling up the crucible to the top with sand. After a few days, more or less as the quantity of charcoal has been much or little, the colour will have disappeared. Distillation affords vinegar colourless, unless pushed too far.

With regard to the theory of the acetous fermentation, and the formation of vinegar, or *acetic acid* as it is called, in its pure form, little is certainly known. It may be admitted as a fact that it is almost exclusively the alcohol of the fermented liquor which is changed into vinegar; and the question is, What is the nature of the changes? Lavoisier, finding that oxygen is absorbed during acetification, concluded that its presence and absorption are indispensably necessary; that the oxygen enters into the compositon of acetic acid; that acetic acid is alcohol *plus* oxygen; and that the change effected by the acetous fermentation is the oxidation of the alcohol. But the facts stated by T. Saussure tend to prove that the oxygen absorbed during the acetous fermentation does not enter into combination with the alcohol; but acts the very different part of abstracting some of its carbon combining with it, and thus forming carbonic acid, which then remains a separate compound, either exhaling or remaining mechanically mixed with the resulting liquor.

Vauquelin conceived that the ferment takes both hydrogen and carbon from the alcohol, leaving therefore an increased ratio of oxygen, and thus converting it into acetic acid, while ammonia and an oily substance are formed; but the production of these two compounds seems not to have been ascertained.

From the facts ascertained by Saussure, it might be supposed that nothing happens in the acetous fermentation except the abstraction of carbon; and that acetic acid is alcohol *minus* carbon. But that this cannot be the case a very little consideration will suffice to show. There are two analyses of acetic acid. According to Gay

Lussac, it is constituted of carbon 50·22, oxygen 44·15, and hydrogen 5·63. According to Berzelius, of carbon 46·83, oxygen 46·82, and hydrogen 6·35. Assuming the analysis which gives less carbon, namely, 46·83 per cent., and comparing it with Saussure's analysis of alcohol, viz. carbon 51·98, oxygen 34·32, and hydrogen 13·70, we find that 100 parts of alcohol contain 5·15 more carbon than 100 parts of acetic acid. Suppose, then, that the oxygen, absorbed during the fermentation which changed the alcohol in acetic acid, has combined with and carried off 5·15 parts of carbon, then the constitution of 100 parts of the resulting liquor so changed would be as follows: —

Carbon - - -	49·362
Oxygen - - -	36·183
Hydrogen - - -	14·442
	99·987

which is very different from the conposition of acetic acid as represented by Berzelius, viz.

Carbon - - -	46·83
Oxygen - - -	46·82
Hydrogen - - -	6·35
	100

And if besides supposing, as some have done, that during acetification the action of the oxygen absorbed was not only to combine with and remove carbon from the alcohol, but also to combine with some of its hydrogen so as to form water, then the result must be that the quantity of carbonic acid produced cannot contain all the oxygen which has been absorbed during the fermentation. This result, however, is contradicted by the statements of Saussure: according to him the volume of carbonic acid produced is just equal to the volume of oxygen which has disappeared. This shows that all the oxygen was expended in forming carbonic acid; for during the formation of

this acid gas the volume of oxygen undergoes no change, its specific gravity only being altered. Thus, none of the hydrogen could have been removed by the oxygen absorbed.

The inference from all that has been here said is, that although it might be supposed that the action of the oxygen absorbed was to carry off as much carbon and hydrogen from alcohol as would reduce the proportions of its elements to those of the elements of acetic acid; such a supposition cannot be admitted, because it is opposed by known facts. And when we consider that fermented liquors, totally prevented from all contact of oxygen, will nevertheless turn completely into vinegar, and no appreciable gas will be generated, one would be inclined to suppose that the change of alcohol into vinegar is produced without any change in the ratio of the elements, by some difference in the mode of combination. Yet here again our conclusion is opposed by analysis, which declares the elements of alcohol and acetic acid to exist in a very different ratio. On these accounts our safest inference will be that the nature of the change which produces acetic acid from alcohol is as yet not certainly known.

In the absence of facts hypothesis may be substituted. After some consideration, I feel inclined towards the following explanation:—Perhaps it is near the truth to suppose that in the formation of vinegar the constitution of the alcohol is subverted; that the elements of the latter re-combine in such a ratio as to produce vinegar; and that the residual quantities of the elements not required for the vinegar unite and form some other compound. What this other combination is now becomes the question. We must recollect that when vinegar is formed a peculiar glutinous matter is always deposited, the nature and analysis of which have never yet been ascertained: this may be the other combination produced from the remaining quantities of the elements of the alcohol. In this view we do not notice the absorption of oxygen which sometimes occurs: this may

or may not happen; it is not essential; for vinegar is formed where there is no access of air, as appears by the experiments of Beccher and Vauquelin.

The experiment of Beccher is simple and convincing; and is of too much consequence to be passed by with a mere allusion. His object, in the experiment which he recites, was to ascertain if vinegar could be formed from wine, the alcohol being prevented from escaping. He says, "Nos ut hæc accurate sciremus, phialam vitream vino *replevimus*, orificio ejusdem colliquefacto, et digestioni exposuimus, ac *fortissimum* acetum accepimus, simul et constantissimum." * Here, then, was wine contained in a bottle sealed by melting its neck, the contact of air rigidly prevented, no oxygen absorbed, no carbonic acid given off, yet very strong vinegar is produced. This seems to prove decisively that oxygen is not necessary to acetification; that it is absorbed incidentally, no doubt by some vegetable substance present; and that therefore an explanation of acetification need not be embarrassed by accounting for a phenomenon which is not a part of the process to be explained.

There is a difficulty, however, which the theory of acetification has to encounter, and which must be stated, although it is not in our power satisfactorily to explain it. It is the opinion of chemists, that vinegar is formed at the expense of the alcohol. Now there are cases where vinegar is formed, and where the previous existence of alcohol cannot be detected. The water in which gum has been dissolved, if left for some time in a warm temperature, becomes sour, on account of the formation of vinegar; yet at no period does any thing resembling the vinous fermentation occur, nor has alcohol been discovered in it. There is, in short, a necessity for admitting one of two things;—either vinegar may be formed without its elements having previously existed as alcohol; or solution of gum affords alcohol by an imperceptible fermentation; which alcohol instantly passes into the state of vinegar.

* Physica Subterranea Lipsiæ, p. 184.

When wheat is steeped and pressed in water, the water after some time becomes acetous: but here there is no difficulty, for alcohol may be detected; and we may hence infer, that in other cases where grain is concerned and vinegar formed the elements of the latter may previously have existed as alcohol, although so transitory was their existence as such that the alcohol escaped observation.

Vinegar is not always the result of fermentation: it is known to exist, ready formed, in various vegetables; but in quantities so small as to prevent its being economically available.

The acetous like the vinous fermentation does not take place unless assisted by a proper ferment: wine deprived of its natural ferment, by fining, will not turn sour, and such wine is therefore rejected by vinegar makers. However imperfect our knowledge may be of the vinous ferment, we know still less of the acetous. There is, indeed, reason to suspect that their natures are not very dissimilar. Considerations have been already adduced which render it probable that some modification of gluten is the agent which excites the vinous fermentation. It has been found also, that when sugar or starch is mixed with water in which wheat gluten had been fermented there is a speedy production of vinegar, and without contact of air or any appearance of fermentation. Here the gluten acted as the acetous ferment. When infusion of malt is fermented, the yest which excites the vinous fermentation will also run the liquor into the acetous stage, unless it is prevented; and it has been already shown that the agent in yest which excites fermentation is gluten or a modification of it. In the same manner, the natural ferment which exists in the grape will first excite the vinous fermentation in its juice, and afterwards the acetous. The matter which subsides from vinegar is of a glutinous nature, and this is very active in exciting the acetous fermentation in weak alcoholic liquors.

A cask in which vinegar has been already made is known to turn a fermented liquor sour sooner than any

other; and on this fact is founded a common process for making vinegar. Sugar added to vinegar will add to the acidity, without perceptibly undergoing the vinous fermentation. The matter which subsides from wine vinegar, or from wine partly soured, also acts as an acetous ferment: dregs of wine and vine twigs act similarly, because they contain the same principle.

There is this difference between the vinous and the acetous ferments, although in other respects they are so closely allied, and are probably but modifications of each other. The vinous ferment is capable of exciting either the vinous or the acetous fermentation: while the acetous ferment can produce only the acetous fermentation.

Besides the action of ferments, there are other causes which produce acetification, and in a manner which it seems altogether impossible to explain. Homberg informs us that motion is singularly efficient. He states that wine not in the least acid having been included in a bottle, and perfectly well stopped, was fastened to one of the sails of a windmill, and by being kept thus in motion during three days it was converted into very good vinegar. Perhaps this fact, if prosecuted, might be turned to advantage in the process of vinegar-making.

Section III.

PUTREFACTIVE FERMENTATION.

The last stage of spontaneous decomposition is the putrefactive fermentation. It is the final change which breaks down all organised matter, subverts all its former constituent affinities, and reduces its elements either to the simple form, or to a less complex and more permanent state of existence. It is that change which all life, whether animal or vegetable, is doomed to undergo, and which resolves all organic structures into the inanimate materials of which they had been originally composed.

Chemical writers have divided this process into two others; one affecting vegetable substances, and the other

acting on animal matter. The former only has been generally considered as a stage of fermentation; and the latter is often described in an undecided way, as merely a process named putrefaction, without being considered as a case of fermentation. Both seem to be equally entitled to the name of fermentation; they only give origin to different results, and resolve the subject-matter into different combinations derived from different elements. Because the proper subject for the vinous and acetous stages of fermentation is vegetable matter, we are not to conclude that none other but vegetable matter can undergo the final stage. On the contrary, we know of animal substances which undergo the three stages of fermentation; witness milk, from which it is possible to obtain alcohol or vinegar, and which finally putrefies. Solutions of animal matter, as broths, acetify very readily, and they also readily putrefy.

The distinction has been founded also on the nature of the elements contained in the subject-matter, and the combinations into which it is ultimately resolved. When vegetable matter undergoes what has been considered the putrefactive fermentation, its oxygen and part of its hydrogen unite and form water, while another portion of its hydrogen combines with carbon, and forms carburetted hydrogen; but the chief part of the carbon remains in the simple form. If air be admitted, carbonic acid also s produced. When animal matter undergoes putrefaction, its elements, which, in addition to those of vegetables, contain nitrogen, arrange themselves differently. The compounds produced in the case of vegetables are formed; and ammonia, the result of the combination of nitrogen and hydrogen, is abundantly produced. Phosphorus and sulphur also occasionally form combinations with hydrogen, and afford complicated products. The production of ammonia is what has been often considered chiefly to distinguish the putrefaction of animal matter from the analogous changes produced on vegetables, and which have been supposed to constitute the putrefactive fermentation. But on the

formation of ammonia no such distinction should be founded; for it is produced in the case of substances decidedly vegetable, many of which contain azote. This is well known to happen with gluten of wheat. I have observed that mushroom catsup, when under process of putrefaction, generates ammonia abundantly; the ammonia and carbonic acid, formed at the same time, unite; the carbonate of ammonia remains dissolved in the liquid; and if any other acid be added, the carbonic acid escapes by effervesence. The existence of nitrogen in mushrooms, thus proved, establishes a connexion between this vegetable and animal matter, which, indeed, the similarity of taste might have anticipated. Straw kept continually wet for a length of time exhales a very perceptible smell of ammonia. During the putrefactive process which the indigo plant is made to undergo, in order to develop its colour, ammonia is evolved.

The cause of the remarkable fetor which is diffused by putrefying matter is not well understood. In the case of vegetable matter, none of the gases emitted have in their own nature any smell. In the case of animal matter, the hydrogen discharged often holds phosphorus and sulphur dissolved, and the compounds are remarkably fetid; but these substances are incapable of accounting for the whole of the odour perceptible. We must conclude that some of the animal or vegetable matter, or some unknown substance, is therefore held in solution beside.

The circumstances which attend the putrefactive fermentation resemble those which are required for the other stages of fermentation. Water must be present, and a moderately warm temperature must be sustained. The process having once commenced, the temperature is spontaneously elevated, and continues while the decomposition goes on actively. If the quantity of matter putrefying be small, the heat is dissipated as fast as generated: hence there is no accumulation. Matter in this state of fermentation will affect other matter, whether animal or vegetable, so as to induce the same state as if

the latter had been inoculated with a ferment. And it is well known that the effluvia from putrefying matter are exceedingly noxious to life, and capable of deranging the functions of animals so as to induce diseases and destroy life even suddenly. Putrefaction can only affect matter which does not possess vitality.

If there be no moisture present, vegetable substances may be preserved for a great length of time: instances of this kind are so common, that none need be adduced. We know also, that the greater the quantity of solid matter, compared with the quantity of liquids in any given bulk, the less easily does putrefaction take place. In like manner, if the moisture of animal bodies be exhaled, they may be preserved almost indefinitely. The instances of preservation derived from what are called *mummies** are irrelevant, on account of the variety of means adopted to preserve the bodies. But the catacombs of Palermo, where no other process is adopted but merely the evaporation of the moisture by heat, afford us good instances of the preservation of animal matter, and of the permanence of its constitution when moisture is not present. The popular and lively tourist Brydone gives us the following account: — "This is a vast subterraneous apartment divided into large commodious galleries, the walls on each side of which are hollowed into a variety of niches, as if intended for a great collection of statues. These niches, in place of statues, are filled with dead bodies, set upright on their legs, and fixed by the back to the inside of the niche; their number is about three hundred: they are all dressed in the clothes they usually wore, and form a most respectable and venerable assembly. The skin and muscles, by a certain preparation, become as dry and hard as a piece of stock-fish; and although many of them have been there upwards of two hundred and fifty years, yet none are reduced to skeletons: the muscles, indeed, in some, ap-

* The word *mummy* is said to be derived from the Egyptian word *mum*, wax — this substance being used in embalming. The custom of embalming originated in a vanity amongst the Egyptians of being considered immortal

pear to be a good deal more shrunk than in others, probably because these persons had been more extenuated at the time of their death. I assure you, they are not such objects of horror as you would imagine: they are said, even for ages after death, to retain a strong likeness of what they were when alive; so that, as soon as you have conquered the first feelings excited by these venerable figures, you only consider this as a vast gallery of original portraits, drawn after the life, by the justest and most unprejudiced hand."

It is well known that those bodies which perish in the burning sands of Arabia are preserved by the desiccation which the flesh undergoes in the arid sand-soil: such were formerly imported into Europe for medical use under the name of Arabian mummy. Next to bodies which contain ready formed water, those which contain the elements of water are known to be most prone to putrefaction.

The agency of temperature in promoting putrefaction will best be appreciated, by adducing instances where it is retarded by absence of the necessary warmth. A number of striking instances have been collected by Boyle. "At Modena," says Bartholin, "they lay up snow in their reservatories; where I have seen them, during the heat of summer, long preserve the flesh of animals from corruption." Captain James relates that in May he drew up from under water five barrels of beef and pork, which, although they had lain there all the winter, were not the worse. Sminlerus mentions that a large quantity of snow, falling from a part of the Alps, buried above sixty Swiss soldiers. The bodies lay until the beginning of the next summer; when the snow being somewhat dissolved, they were found fresh and uncorrupted. Captain James says, "Near six months after our gunner was dead and committed to the deep, at a considerable distance from the place we were now in, our master espied his corpse in the ice under the gun-room ports: whence having dug him, we found his scent no more disagreeable than when first thrown overboard; but his

flesh would slip up and down his bones like a glove on a man's hand." But the most remarkable instance of all is the following: — In 1799 a Toungouse, coasting along the peninsula of Tumut in Siberia, perceived, in the midst of a block of ice, an enormous mass of something, the nature of which he could not ascertain; he therefore took no further notice. Next year happening to be at the same place, he observed that some of the ice had thawed away; and at the close of the next summer the thaw had proceeded so far as to disclose the side of a monstrous animal. At the end of five years from this first observation, the surrounding ice had so far melted that the animal had tumbled down from the block: it proved to be a mammoth. Its skin was perfect, and was covered with a coarse, thick, reddish wool, and black bristles: its flesh was in such preservation, that for two years the arctic bears, the wolves, foxes, and dogs, fed on it. How many centuries, or hundreds of centuries, this animal had lain incarcerated in its icy prison is a problem of deep interest. If any more instances of the antiseptic quality of cold were required, the well-known frozen markets of Russia would be sufficient.

Thus we find that putrefaction does not take place at low temperatures: and it seems that the agency of cold is equivalent to the preservation effected by the expulsion of all the moisture present in the animal matter. To render moisture solid is precisely the same as to withdraw the moisture altogether. We know that putrefaction is also prevented by an elevated temperature. For any thing known to the contrary, flesh would be preserved from putrefaction as long as it could be kept at a boiling temperature. Herculaneum was destroyed A. D. 79 by an eruption of Vesuvius, and in a short time burned beneath the shower of hot ashes thrown up from the volcano. The high temperature, no doubt, evaporated the moisture from the bodies, and thus preserved them; for many were found preserved. "Within the houses they found dead bodies, medals, furniture,

and things of all kinds. I was told that the bodies mouldered away when exposed to the air." * This mouldering on exposure to air is a common occurrence to bodies preserved out of contact with the atmosphere.

When once the temperature has been elevated sufficiently to produce putrefaction, the chemical action which ensues develops a sufficiency of heat to continue the process; and if the quantity of matter be great, the elevation of temperature may become considerable. Roses have a remarkable tendency to spontaneous heating: even a very moderate heap of them, not occupying more than the bulk of two cubic feet, if left together for a few hours, will heat in the centre, so as to raise the thermometer to 100° and sometimes even to 120°. A large quantity of hay, if stored while damp, often heats to such an extent as to take fire; and great mischief is sometimes thus occasioned. I say nothing of the spontaneous combustions which happen when heaps of charcoal or common coal have got wet, as this depends on a different cause.

The septic tendency of animal matter is counteracted in a variety of other ways: as by the action of charcoal, of common salt, nitre, and other salts; by acids, as the acetic, the sulphuric, the muriatic; by tarry, bituminous, and resinous aromatics; by various spices; by alcohol, and even by sugar. According to Statius, the body of Alexander the Great was preserved in honey. And we find the following account recorded by Abdollatiph the Arabian traveller: — "A person worthy of credit told me, that during a search for treasure near the pyramids an oblong close vessel was found. This being opened appeared full of honey, whereof the party present ate; but some of them soon observing hairs sticking to their fingers, on farther examination discovered that a young child, with a certain jewel or ornament on its body, was inclosed."

In the putrefaction of vegetable matter, the only ele-

* Cochin and Bellicard's Herculaneum. — *Letter.*

ment which remains is carbon, mixed with any earths and metallic oxides which the vegetable contained. This carbon, if the atmosphere be freely admitted, slowly combines with oxygen, forms carbonic acid, and at length the whole disappears. But if air be excluded, the carbon remains for ages unchanged. At the Giants' Causeway, in the north of Ireland, we find a coal lying over a rank of columns of basalt, with another rank of basaltic columns standing over it. This coal, which has a bituminous fracture, and burns with a white flame, is clearly the carbon of some ancient vegetable structure. We can plainly discover in it the grain of the wood, and the knots; and these latter are sometimes perfectly sound and unchanged either in texture or the natural colour of wood, although taken from the centre of a block of coal. I have one of these in which the knot of sound wood grows darker and darker from the centre, until at length it blackens into the nature of the coal from which it was taken. This coal is not pure carbon, but contains also hydrogen. Nothing is more common in bogs than to find trunks of trees not only undecayed but even of a stronger texture than when growing. The bogs themselves may be looked upon as the carbonaceous remains of ancient vegetables, which, being buried and immersed in water, have not had access of air to combine with oxygen. Such accumulations of carbonaceous matter are not only in themselves of a most unchangeable nature, but impart their qualities even to animal substances enveloped in them. The discovery of dead bodies buried at considerable depths in bogs, and in a high state of preservation, proves the age of the bodies as well as the antiseptic quality of the bog. Such discoveries have been frequently made in Ireland. The following has been recently published by Mr. Petrie:— "In the summer of 1821 the body of a man was found in a bog in the county of Galway. The bog was about ten feet and a half in depth, and the body lay about nine feet below its surface. It had all the appearance of recent death when discovered, excepting that the abdo-

men was quite collapsed; but on exposure to the atmosphere it decayed rapidly. The face was that of a young man of handsome features and foreign aspect; and his hair, which was long and black, hung loosely over his shoulders. The head, legs, and feet, were without covering; but the body was clothed in a tight dress, covering also the limbs as far as the knees and elbows. This dress was composed of the skin of some animal, laced in front, and having the hairy side inwards." * This body must have been of great antiquity.

The following is from an early volume of the Philosophical Transactions: — "Jan. 14. 1674, during a great snow in Derbyshire, a man and woman were lost; and being found in May following, were buried in a peat moss, where they lay twenty-nine years. They were again found, and appeared no way altered; the colour of their skin being fair and natural, and their flesh soft as that of persons newly dead. They were occasionally exhibited during twenty years after: the man still remained perfect, the woman a little less so. They were then buried in a church-yard grave, where they speedily decayed." There are many other instances on record, but the following may suffice: — In 1747, a man digging a peat-moor in Lincolnshire found the remains of a woman about six feet below the surface, in a high state of preservation. From parts of her dress she appeared to be of the better order of society. The body was doubled up in the bog. The skin was soft and pliable, stretching like a piece of doe leather, and was as strong: it was of a tawny colour. The nails of the hand were as fresh as in life. Bones, skin, gristle, nails, and hair, were the substances which appeared best preserved. These remains were deemed very ancient. †

It seems very probable that the carbonaceous matter of bogs possesses an antiseptic quality in consequence of some modification which it and the other elements have undergone during gradual changes. It is certain that it

* Dubl. Phil. Journ i. 433.
† Phil. Trans. ab. by Hutton, &c. ix. 265.

is a common practice amongst the inhabitants of bog districts to tan horse hides by merely immersing them in a lough of bog water, and the process succeeds tolerably. That such water contains something actually dissolved from the turf is plain, from the fact that its colour is brown, just as if tannin, or something of an approximate composition, had been dissolved in it.

In the putrefaction of vegetable matter, the changes which take place are more simple than those which occur in the case of animal substances. Lavoisier represents the nature of the change as follows: — "The constituent elements of the bodies cease to continue in equilibrium, and form themselves into compounds which consist of two elements only: the whole of the hydrogen is dissipated in the form of gas, and the oxygen and carbon escape in the form of carbonic acid; so that when the whole process is finished, especially if there had been a sufficiency of water present, nothing remains but the earth of the vegetable mixed with a small portion of charcoal and iron. Thus putrefaction is merely an analysis of vegetable substance, during which the whole of the constituent elements is disengaged in the form of gas except the earth, which remains in the state of mould." But the changes which take place during the putrefaction of vegetable matter appear to be more complicated than this, under certain circumstances. When the putrefaction takes place in the open air, the decomposition is found to happen in the manner described by Lavoisier: but when the air is excluded, as when the decomposition takes place under water, the products are certainly different; for then we obtain carburetted hydrogen, as well as carbonic acid.

What remains, when the decomposition has totally broken down the structure of the vegetable, is a black pulverulent substance, consisting of much carbonaceous matter combined, no doubt, with some hydrogen, a little earthy matter, and traces of metallic oxides. This constitutes what is called vegetable *mould*, and is also the chief ingredient in vegetable manure. It is the sub-

stance into which all vegetable structures are at length, although but slowly, resolved previously to its regeneration into the vital state when assimilated into the composition of some living plant.

The changes produced in animal matter by putrefaction are more complex, and more rapidly effected, provided that there is access of air. If there be no access of air, the change is much more slow. It has been ascertained, that where so many as a thousand or more dead human bodies were collected together, and the air was excluded by their lying over each other, it required thirty years to destroy their organic structure completely.

When the contact of air is prevented during putrefaction of animal matter, as in the case just alluded to, or where the animal matter has been for a long time immersed in water, a remarkable change is produced. The flesh is converted into a substance intermediate between wax and lard, and hence called *adipocire.* This substance is, in fact, a soap in which the alkali present is ammonia, and the fatty portion is the altered animal matter. The manner of its production is quite obvious. Muscular flesh is composed of oxygen, hydrogen and nitrogen. During its spontaneous decomposition, it is easy to conceive that some of the hydrogen may saturate itself with nitrogen, and form ammonia; while the remainder of the hydrogen may remain combined with carbon and a little oxygen, in such proportions as to form an oil or fat. This, by combination with the ammonia, would form a peculiar kind of ammoniacal soap; and such seems to be the nature of adipocire.

A few months' exposure of muscle to the action of a running stream of water is sufficient to effect this singular change; but many years are required to produce it when the animal matter is merely secluded from air by being buried in the ground.

Section IV.

COUNTERACTORS OF FERMENTATION.

From different parts of this volume it may be collected that the vinous fermentation can be moderated, or finally checked, by various methods. Reduction of temperature has an immediate effect. Skimming off the head of yest; racking off the liquor from the yest lying in the bottom of the containing vessel; and precipitating the yest, which remains suspended in the liquor, by different substances to be described hereafter, —all conduce to the same end. Caustic alkalies or lime extinguish the vinous fermentation at once: but this fact is of no use, as the liquor is rendered worthless, and it shortly runs into putrefaction.

The fumes of burning sulphur have been long known to counteract the vinous fermentation. All that is required to be done is to burn a quantity of sulphur in the vessel which contains the fermenting liquor, keeping its mouth covered, until the oxygen of the air present is converted into sulphurous acid gas. If the fermentation be conducted on a small scale, as in a cask, sulphur matches may be burned in the cask until the air contained in it is sufficiently polluted. The chief advantage of this antiferment is, that being volatile it escapes from the liquor, and then it is as fit as ever for continuing its fermentation. Hence it suspends but does not extinguish fermentation, which is a great advantage. Or sulphurous acid obtained by any other process may be used; or it may be condensed in water, as a stock, and kept well stopped in bottles.

There are other modes of attaining the same end "which are little known, and perhaps more convenient than the process above described. One of these is the introduction of the black oxide of manganese, the properties of which in precipitating the leaven are similar to those of sulphurous acid. But a more ready, and perhaps the

most convenient process of all, is the use of the sulphate of potash; a salt not difficult to prepare, but, for want of a demand, not now to be procured from the trading chemists. A very small quantity of this salt, which possesses the advantages both of convenience and durability, is sufficient to answer this purpose. A drachm, for example, will be enough for a pipe of liquor. It communicates no taste, and can readily be managed with the greatest accuracy, by proportioning the quantity to the particular circumstances. Makers of sweetmeats will not be displeased to know, that by the use of the same substance the fermentation of syrups and preserves may also be effectually prevented. From some partial trials which it is unnecessary to detail, I have reason to think that this object may also be attained by the use of oxymuriate of potash; a salt absolutely tasteless, and easily procured." *

The means of counteracting the acetous fermentation are not very different from those which check the vinous. Racking off from the acetous ferment, whatever its nature may be, and exposure to a very high or a very low temperature, are chiefly efficacious. Seclusion from oxygen gas, or from the atmosphere, retards but does not prevent it. The addition of a large quantity of alcohol obstructs the acetous as well as the vinous fermentation; but the former kind is fed by a small quantity of alcohol. As vinegar acts as its own ferment, we must be careful, when the acetous fermentation is to be guarded against, to correct the first approaches of acetification by the continual application of some antacid, as alkalies or alkaline earths. For the acid once formed, an inoculation takes place which speedily infects the whole volume of liquid, and acetification goes on rapidly.

As to the putrefactive fermentation, enough has been said of the means of arresting it. The nature of antiseptics is well understood in domestic economy, and they have been already enumerated. Charcoal powerfully resists putrefaction, whether of animal or vegetable sub-

* Macculloch on Wine-making, p. 190.

stances: but for this purpose it should have been either recently made, or at least recently ignited out of contact of air, as included in sand. I have not the least doubt but that meat may be preserved by means of powder of new charcoal; the meat in slices being well packed in the powder, and the whole protected from the air. It is well known that meat which has acquired a taint from long keeping may be restored nearly to its original sweetness by being boiled in water, along with well burnt and newly prepared charcoal broken into very small parts and used in considerable quantity.

Stakes of wood which are to be driven into the ground, and are intended to resist the rotting influence of damp, are rendered capable of doing so by being charred on the surface; that is, scorched in the fire. And a well known method of keeping water sweet on long voyages is to keep it in casks the insides of which have been carefully charred. The power of charcoal in purifying putrid water is greatly assisted by a small quantity of lime. *

CHAP. VI.

BREWING.

Hitherto the subjects treated of in this volume may be considered as introductory to all those domestic arts which are founded on the process of fermentation. We have examined the nature and constitution of seeds, and have applied the facts ascertained to the explanation of the making of malt. We have also investigated the theory of fermentation, so as to render the practical part easily comprehensible. All this became necessary to the explanation of the processes equally of the brewer, the distiller, the vinegar-maker, the wine-maker, and the baker.

* For a number of useful details on this subject, see Crell's Journal, ii. 279.

We now proceed to the consideration of these different subjects in detail, beginning with BREWING. This art may be divided into the following subjects:—1. Mashing, in which, for convenience-sake, is included grinding; 2. Boiling, hopping, and cooling; 3. Fermentation in the tun; 4. Cleansing; 5. Fining; 6. Attenuation; 7. Storing, and other particulars; 8. Water; 9. Colouring matter; 10. Processes for brewing particular kinds of malt liquors, and domestic brewing; and, 11. Observations on the present state of the art of brewing. These shall constitute the subjects of so many sections.

SECTION I.

MASHING AND GRINDING.

We have seen already, that in the malting of grain the conversion of starch into saccharine matter may either be supposed to be effected at once, or that the starch is merely modified during malting so as to be prepared to undergo the change, almost immediately, when exposed to the conjoint action of hot water and its own gluten, some of which always remains unaltered: the latter seems to be the opinion best supported by facts. It may be observed that ground malt is not so sweet, apparently, as to produce an infusion so strongly saccharine as on trial it is found to do; that the saccharine matter is not dissolved away from ground malt by *cold water*, although when once extracted it is so soluble in water of any temperature. If boiling or very hot water be poured on ground malt, the mixture thickens; it forms a close paste with one part of the water which does not allow the rest of the water to pass through it: the saccharine matter is said by brewers to be *locked up;* that is, it does not dissolve in the water. The malt is in this case said to be set: its value is lost; for it retains a great part of the liquor enveloped in the paste, which will not run. Sometimes the parts of the malt lying next the water as it enters will set; and then the paste formed refuses further

passage to the water. It is very easy to trace the cause of *setting*.

On reference to the comparative analyses of malted and unmalted barley, by Proust, it will be found that in 100 parts of barley there are 32 parts of starch; but in 100 parts of malt there are 56: and although we may feel disposed to believe that these 56 parts of starch are for the most part modified in some such manner as already described, yet experiment has proved that some of it remains absolutely unaltered, and starch has been even detected in small quantities in old ale.

The property of starch is to dissolve and thicken in boiling or very hot water. Is it not then just what we should expect, that when boiling water is poured on malt, containing starch, the whole should thicken up into a paste composed of gelatinised starch, containing the other ingredients of the malt? This accordingly happens; and it is more likely to happen with malt new from the kiln. On this account many brewers expose their malt for some time to the air after being ground.

But if we infuse ground malt in water of such heat as will not set the mixture, yet of such heat as will promote the action of the gluten on the starch, the result of that action will be the conversion of the starch into saccharine matter. If the liquor holding this newly-formed saccharine matter be now drawn off, and water of a much higher temperature let on, it will not produce setting; probably its effect will be to form a little more saccharine matter. After this solution has been drawn off, water actually boiling may be poured on without the least appearance of setting; for there is now nothing to be set. In this way, by using waters of different and increasing heats, the whole starch is dissolved, and is held in solution without producing the least thickening. One would scarcely conceive that this could happen, unless the nature of the starch had been changed during the action which the first hot water had promoted amongst the ingredients of the malt; the result of which was sugar, that had not existed previously in

this quantity in the malt. Boiling water would have dissolved the starch, as such, before there could have been time for its conversion into sugar.

This view of the subject is still further favoured by the fact, that when hot water and ground malt are infused together in the brewer's mash-tun, the sweetness, during the first ten minutes inconsiderable, becomes continually more intense during perhaps two hours; although the water becomes continually cooler, and therefore less capable of extracting sugar from the malt, were its duty merely to extract and not to form. It may certainly be supposed that the increase of sweetness in proportion to the time is attributable to the effects of penetration; but such a supposition is opposed by the fact that cold water left on the malt, for almost any length of time, does not become sweet, but at length sour; while a gentle heat, kept up for an hour, affords a highly saccharine liquor. The well-known conversion of the starch of raw barley-meal into sugar, by mashing with hot infusion of malt, also receives a ready explanation by supposing that sugar is formed during the mashing as well as by malting.

If no such conversion took place, raw barley could scarcely be made to constitute a part of the grist in the mash-tun from which worts are to be extracted. For worts from raw barley are much more liable to fall into the acetous fermentation than the vinous, and could scarcely be made to afford a sound drink.

Whatever the theory may be, we derive the following practical rules from the facts detailed. It appears that neither cold nor boiling water will succeed for producing a good solution of saccharine matter from malt. Cold water acquires little or no sweetness, and forms a spiritless and acescent drink; boiling water forms a mucilaginous liquid, which, whatever it may contain, cannot be drawn off from the grains, and hence is lost. Water of a medium temperature acquires a full sweetness, and readily parts with the undissolved matter. But although water of a high temperature (yet much under the boiling heat) will dissolve or form a greater quantity of saccha-

rine matter from the malt, it is, nevertheless uneconomical: for the malt is in such cases somewhat, although, perhaps, but a little set; and there is a loss of the liquor, because it is held involved in the pasty grains. The second mashing may lessen the loss, but will not compensate the deficiency. It is therefore quite plain that the first mashing should be made with warm water, the next with hot water, and the next with still hotter; for each succeeding mash there is less possibility of setting, as the starchy matter has been removed.

In selecting a proper temperature for the water, our choice should be regulated by two qualities, its sufficiency to extract the saccharine matter, and its insufficiency to set the goods. The result of attention to both points will be the attainment of the greatest quantity and best quality of produce. The perfection of the process may be judged of by the quantity of worts produced: more than the due quantity indicates less strength; less indicates setting.

These positions require modification according to the nature of the malt, and how it had been dried. They are applicable with most effect to the case of pale malt: for in this, whatever starch remains unaltered into sugar exists in its natural state, and will be affected by boiling water as already described. But if the malt has been exposed to a high heat, as it often is, with the view of affording a deeper coloured infusion and an altered flavour, the starch is more or less scorched; and in proportion as it is scorched, it becomes, within certain limits, more soluble in hot water without thickening it. In brown malt, the scorching is such as to destroy both the starch and the saccharine matter, and it contains little more than a brown colouring matter. The higher the temperature at which the malt has been dried the hotter the water made use of for mashing may be, and the less must be the possibility of its setting. Hence pale malt, as containing much unaltered starch, must be mashed at a moderate heat; amber-coloured malt, as containing starch in a slight degree scorched, will allow a

hotter water; and very brown malt will admit water of any temperature without injury, because the starch is totally changed by heat. But malt which had been originally badly made, or which had been dried on the kiln before any considerable quantity of starch had been changed into sugar, will require the temperature of the water used in mashing to be lower than pale malt; and if barley-meal which had never been malted is used, the heat of the mash should be lowest of all. The opinion here given, that highly-dried or scorched malts permit the use of hotter mashing water, is at variance with what is commonly maintained by brewers. But it is matter of fact that starch, when exposed to a temperature above 212°, changes colour, and becomes more and more soluble in cold water; and when the starch has become brown, it is perfectly soluble in cold water, for its nature is then completely changed; it is converted into a kind of gum, and is used by calico-printers under the name of British gum. In such cases, it is impossible that even boiling water could produce a tendency to setting such highly-dried malt, or that it could have any other effect than that of more perfectly extracting every thing soluble from the grain. A notion such as is here advanced was entertained by Mr. Combrune; but on this subject he was so singularly misled by some ill executed and deceptive experiments on the heats at which the different colours of malts are produced, that his statements are of little value, and the less so, as they are complex, obscure, and affected. Enough of these experiments will be learned from his assertion, that at 175° malt becomes charred; and that at 210° the malt "hissed, fried, and smoked abundantly." We must, therefore, infer that boiling water poured on malt would inevitably set it on fire, but for the stifling influence of the water. And as water of 175° is often used for a mash, the result must be the charring of the malt.* This subject will be hereafter resumed and modified by considerations yet to be adduced.

* Combrune on Brewing, 1804, p. 110.

It is well known to practical brewers that water is capable of producing worts of very different qualities, according to the temperature at which it is mashed; and they explain the fact by supposing that the ingredients of the malt are soluble, more or less, in water in proportion as it is more or less hot. But there can scarcely be supposed to exist such a difference of solvent power in waters having so confined a range of temperature as is used; and we may with more probability conceive that the gluten and starch act on each other, more or less, so as to form sugar, according to the temperature at which the chemical changes are promoted. The highest heat generally employed is about 20° below boiling; and this only for last mashes. This ready separation of the undissolved matter will also depend on other causes. If the malt be ground to a very fine powder it will set with water at a less elevated temperature than if it be more coarsely ground: it will part with the water, so as to form a transparent solution, with more difficulty; and the whole of the valuable portion of the malt will not be extracted. When the malt is merely bruised or broken into moderately small parts, the water penetrates the substance of each, acts upon its interior, and afterwards is drained out of it, being in a manner strained by percolation through its interstices. It is, certain, however, that but for the reasons just assigned the more minutely the malt is divided in grinding the more readily would its saccharine part be dissolved away; and it will be still a good method to grind tolerably fine, provided that due agitation be used. But if considerable agitation be not used, the fineness of the powder, by forming a paste permeable with difficulty by water, will rather obstruct than assist the solution; and a weak extract will be obtained. Length of time in mashing will compensate coarse grinding. If the malt be coarsely ground, allowing the hot water to act on it for a greater length of time will at length dissolve every thing soluble from the grain. But delays are particularly dangerous in brewing; and often to them

may be attributed the commencement of sourness which has ultimately destroyed the produce. In all cases, the husk of the malt must be completely detached from the grain ; for so refractory does it prove to the permeating influence of water, that an unbruised grain of malt will remain long submerged without giving out its saccharine principle. But although the husk should be detached, it should by no means be broken down into powder. On the contrary, its hardness, size, and substance, have the effect of keeping the farina open and porous ; the water is thus the better allowed to permeate, and there is less risk of setting.

The principles which ought to direct us in the grinding of malt seem therefore to be as follow : — We should, if possible, totally detach the husk. We should break down the cohesion of the interior of the grain in such a manner as that no part of its natural hardness should remain unsubdued. But the perfection of the process would be, if, having succeeded in subduing the cohesion of the grain, its parts were still to remain cohering with just as much force as would prevent their falling into flour, yet would permit the complete entrance of the water amongst all the disintegrated particles. The nature of this would be best expressed by the word *crushing*. Were it possible to effect all this, the advantages would be, that it then becomes not only allowable but highly beneficial to use water of a higher temperature in mashing than ought otherwise be used ; such as will with more effect produce the solution or evolution of the saccharine matter (whichever the truth may be), or, in technical language, produce a rich extract. This would be accomplished without danger of setting or enveloping, instead of evolving the sweet principle ; and, after the mashing, there would be found no difficulty in drawing fine transparent worts, without holding entangled any insoluble parts of the malt.

Unfortunately, in the present state of the art, it is not found possible to attain all the objects here described. There have been many attempts to construct grinding

machinery capable of fulfilling all intentions; but none have perfectly succeeded. The common mill, constructed of two horizontal circular stones, such as is used for grinding flour, succeeds but indifferently. No regulation of distance between the stones is sufficient to prevent some grains from being broken into an impalpable powder, and others from being scarcely bruised. Steel mills, which cut the grains by teeth, somewhat on the principle of a coffee mill, have also been employed, and in their action appear to be superior to the mill-stones; but even this breaks down much of the malt into flour. The best contrivance is, probably, a pair of revolving rollers, made of case-hardened iron, regulated at such a distance asunder, that the grains, in passing between them, are not cut or broken, but bruised; and the broken-down particles are forced together into a kind of secondary contact, they still cohering sufficiently to prevent the entrance of the water from detaching them. The action of the rollers condenses the malt so much that there is a considerable elevation of its temperature.

Beside attention to temperature and the degree of fineness in grinding, there are many other particulars to be observed. If water, duly heated, be poured on malt properly ground, and both be allowed to remain undisturbed, the malt will subside to the bottom: it will part with its saccharine matter to the water immediately in contact with it; will saturate it; and the water thus saturated, having now become specifically heavier, will remain at the bottom along with the malt. The lower stratum of water cannot dissolve any more; consequently, the remainder of the saccharine matter, perhaps by far the greater portion of it, will remain unextracted from the malt. The process of solution, therefore, terminates, and the upper stratum of water remains unimpregnated. Hence the necessity of agitation; and accordingly the brewer employs it almost incessantly during the mashing. Formerly the duty was performed by men, who stirred up the malt in the water with long poles called *oars*, but of late years machinery has been introduced Of

this machinery an adequate idea may be formed by conceiving the malt and hot water to be contained in an immense circular tub. In the centre of the tub is erected a pillar; and on this pillar, as a centre, a horizontal arm turns, which extends to the circumference of the tub. This arm is a bar, on which are affixed a double rank of prongs similar to garden rakes, which stand at right angles on the arm, and turn on it as a centre, but contrarily to each other. The action of the whole apparatus is this: the horizontal arm turns on its centre (the pillar); it traverses round the whole tub; and, while doing so, the rakes are turning round the arm as a centre, and raking up the malt from the bottom in all parts successively. The rakes driven by machinery are infinitely more effectual than oars in presenting new parts of the malt to the water, and promoting extraction: it is one of the greatest of the modern improvements in the art, not only saving manual labour, but executing the duty incomparably better. The tub which the rakes traverse is of a vast size in some breweries, containing several hundred barrels' measure. It is called the *mash-tun*.

After the agitation of the malt and hot water, during the mashing process, the mixture ii allowed to settle would deposit the grains, and a transparent liquor would float above. The transparent liquor is the portion which it is the object to separate, and this can be only conveniently separated by straining. To obviate the vast trouble of transferring the contents of the mash-tun to a straining apparatus, the mash-tun itself is contrived to be a strainer. This vessel has a wooden bottom like any other tub; but a few inches above this it has a movable or false bottom, composed of metal plates, which lie closely together, and fit the tub perfectly all round as one level plane. The metal plates are perforated with thousands of funnel-shaped holes, the widest part of the funnel-hole being downwards, and the hole in the upper surface being so small as to prevent the grains from running through. On this metal plate the malt lies.

When the water is first let on, a sufficiency should

be used to form rather a stiff paste with the malt: for equal diffusion is more easily attained with a small than a large quantity of water, and setting is more certainly avoided. Two barrels of water to each quarter of malt will be about sufficient to form this paste. The rake machinery should then be put in motion until an even mixture is obtained. The rest of the water, say one barrel per quarter, is then to be let on, and the agitation continued for a length of time. The rake machinery is now to be stopped; and, to prevent cooling, the mash-tun is to be covered. The whole is to remain at rest for a period equal to the time during which the agitation had been continued. The fine powder will become compressed by, and enveloped in, the coarser grains, and the stratum of malt will act in some degree as a strainer. But for this period of repose, the fine powder would remain suspended in the liquor, and it would eventually run off muddy.

The process of draining off the transparent liquor is then commenced: this is called *setting the tap*. It is readily performed by opening a cock placed in the tub between the two bottoms. Through this, the transparent liquor, now called *wort*, is discharged. It is made to run slowly at first by opening the cock partially; for if entirely opened, the rush of liquor would be so great as to disturb the grains lying on the false bottom, to cause them to plug the perforations, and even to foul the wort which it had been the object to draw off bright and clear. When any wort has been fouled, it should be returned back cautiously on the surface of the grains. After the cock has been running for some time, it may be opened a little more, and closed a little should it run foul.

The first mash is agitated and allowed to rest during a longer period than the second, and the second during a longer period than the third. But the deficiency of time is compensated by the elevation of temperature; the third mashing being hotter than the second, and the second than the first. In thus compensating time by

temperature, the mashing processes are equalised, completed within a short period, and one source of delay is avoided, which is the same as avoiding one source of souring. The advantage of the increased heats of the different mashes is the greater solvent power given to each water, and the more perfect extraction of all the valuable parts of the malt.

If a mashing have been rightly executed, the wort, when drawn, will remain perfectly transparent. Should it let fall a white deposit, it is a proof that the mashing water was not sufficiently hot to take a rich extract. Its taste should be a heavy sweet. The colour should be the same as that of the malt from which the extract was obtained; the more parched the malt had been, the browner will be the wort. But if the wort be much deeper coloured, it may be inferred that the water used in the mash was too hot. The inference will be the same if the malt from which the wort is drawn off should have a slimy feel.

The first wort extracted from good malt is not only by far the strongest and sweetest, but is most delicate in flavour, and will produce the nicest drink; for it was extracted by water of a temperature insufficient to dissolve away the coarser and more disagreeable parts of the grain. The first wort is, therefore, sometimes reserved for superior ales, and the second and third for inferior beers.

Dr. Thomson, alluding to some experiments made by him and others on the large scale, says, "The proportion of starch was usually greatest in the first worts, while that of the mucilage was greatest in those that were last drawn. The saccharine matter also diminishes sensibly towards the end, and at last disappears altogether. The last portions of worts become much more easily acid than the first, and indeed often taste sour even when running from the malt." *

There should be on the surface of the worts a rich white foamy froth. But if the froth is brown, it is

* Papers presented to the House of Commons, p. 47.

said by some to be a proof that the heat of the water used for mashing had been too high. The taste of the malt will be found in the worts: sweetness, burnt flavour, or mustiness, will certainly be communicated. Sufficient has been already said as to the relation which the heat of the water used for mashing should bear to the quality of the malt; but nothing has been as yet stated as to the positive temperature of the water. Indeed nothing positive can be stated, there being such variety in the circumstances which should modify our treatment of the malt in this respect. It is obvious that the relative quantities of the water and malt are to be taken into account. If little water at a high heat be let in upon much malt, at the ordinary temperature, the *resulting temperature* of the mixture may be so low as to be inadequate to the due extraction of the saccharine matter. The nature of the resulting temperature must be here explained, as it leads to important consequences. This temperature will not be the arithmetical mean between the temperature of the malt and that of the water, but will be always hotter and sometimes considerably so. There are two causes in operation, and they modify each other's effects. To explain clearly this statement, let us suppose that a pound of water at 212° is mixed with a pound of water at 60°, the temperature of the resulting mixture will be 136°, that is the degree obtained by calculating the mean of both heats. For adding both numbers together, the half of their sum will be 136. But the same would not happen with a pound of mercury at 212° mixed with a pound of water at 60°: the resulting temperature would be much below 136°, because, although the mercury lost a certain quantity of heat, that quantity was not sufficient to bring up the water an equal number of degrees, different kinds of matter requiring different quantities of heat to raise them to the same temperature. Just so with the malt and water: the malt will require more heat than the water to arrive at the same degree, and hence the resulting tem-

perature of hot water let on cold malt would, so far, be *below* the mean.

In such cases, however, the resulting temperature is always *higher* than the cause above described would have decided it; on account of another principle in operation. If alcohol, or better, oil of vitriol be mixed with water, there is a great increase of temperature owing to condensation. If the saccharine matter of malt be dissolved in water, there is also an elevation of temperature owing to the same cause. This elevation is so considerable that it not only countervails, but exceeds, the effects of the former cause, and the actual temperature produced is above the arithmetical mean. On this subject the following statements have been made:—If barley be mingled with twice its bulk of warm water, the resulting temperature will be very nearly the mean heat. If in another trial the palest malt is used, the result will be above the mean. If highest dried malt is used, the temperature will be so much as 40° above the mean.* No heat is *generated* but in the first mash. Thus in calculating the heats of mash liquors the quality of the grist must be considered.

It has been stated at page 146. that brewers are mistaken in supposing that highly dried or scorched malts do not permit the use of hotter mashing water on account of the risk of setting; and cause was there assigned for believing that there is no foundation for such apprehension. But from the considerations just now adduced, it is plain that, in determining the heat of a first mash liquor, reference must be had to the extent to which the malt had been dried or parched. For as it has been just shown that heat is actually *generated* by the solution of the saccharine or other matter, it then becomes advisable, where pale and brown malts mixed are used, to make some allowance for the generated heat by reducing the heat of the first mash liquor somewhat. If not, the heat of the whole mash, although in no way detrimental to the brown malt, may tend to the setting

* Rees's Cyclopædia, art. Brewing.

of the pale malt which constitutes a part of the grist. This caution is in the present day of no value, the quantity of brown malt used being so little, and that little merely intended for colour. In the use of very low dried malts no particular caution is required.

The sum, then, of the different statements here made, with regard to mashing heats, which, unless thus explained, might appear a little contradictory, is, that in the case of parched malts, high heats may be used without fear of setting the goods; that hot liquors are not so much cooled by parched malts as by low dried malts; and that, hence, if a mash-liquor be of such heat as is properly adapted to a grist composed entirely of pale malt, it will be too hot for a grist composed of brown and pale malt mixed, the latter undergoing a risk of setting by the elevation of temperature created.

The resulting temperature is influenced by another circumstance which brewers always take into account. Malt, when exposed to the air, absorbs water hygrometrically. This water, present in exposed or *mellowed* malt, tends to lower the resulting temperature; and such malt is always mashed with a somewhat hotter liquor, while that which is fresh from the kiln is mashed at a lower temperature. Slack-dried malt, or that which was originally insufficiently dried on the kiln, is to be treated as mellowed malt.

Water of 150° can never be injurious to malt of any kind, or under any circumstances of fineness of the grist, or temperature of the air, or slackness of drying. If a general rule, without reference to particular kinds, can be given, it is this:— For well dried pale malt, provided the atmosphere does not exceed 50°, the heat of the first mash-water may be, but should never exceed, 170°; the heat of the second may be 180°; and for the third, the heat may be, but need never exceed, 185°. Nothing is gained in a third mashing by a higher temperature, unless the extraction of an ill flavour arising from the solution of a bitter resin contained in malt. These degrees are meant to represent the heats which

may be employed for effectually exhausting the malt; but they are varied according to the nature of the drink, and the fancy, or rather the caprice of the brewer. Higher heats need never be used, as they cannot extract any thing more. This part will be resumed hereafter. For the present, it may be sufficient to say, that were the effects of high and low heats found to be equal as to extracting power, and indifferent in other respects, the preference ought to be given to the high heats, because the worts come off proportionately hot, and the risk of innoculation with sourness, which often occurs, is thus avoided. After the mash has been completed, and the wort is in the act of being drawn off, its temperature should be between 140° and 150°. If lower, there is a risk of souring; if higher, the chance is, that the original heat was sufficient to produce partial setting and loss. Another reason is, that in mashing at a high heat the chemical action of the gluten on the starch is rendered more effective in forming sugar. But there is, on the other hand, an advantage in low heats, at least for nice purposes; they extract nothing coarse: a medium that combines both advantages.

Some brewers are of opinion that the last mash should be made with water heated to a lower degree than the preceding. Mr. Combrune and others think that the last should be hottest; and I am of the same opinion, provided it is not above 185° in any case, and provided that the only object is to extract something by the last mashing liquor. The object sometimes is to wash away the remains of the preceding worts absorbed and held by the grains; and when this is the case, the last mashing may be colder, but certainly ought not to be hotter.

Beside the influence on the mashing heat, which the relative quantity of the ingredients exerts, their absolute quantity is not less to be considered. If the sum of the quantities be small, the heat is soon dissipated, the mash quickly cools, and the extraction as speedily ceases;

hence the necessity of using water as hot as can properly be applied. But if the quantities be large, the heat maintains itself so long that there is no occasion for using the highest heat at first, as length of time compensates degree of temperature within moderate limits. A moderately heated water may, therefore, be used in the large way, and the worts obtained will have a more delicate flavour; but the same delicacy of flavour may be obtained in the small way, if contrivances be used to maintain the temperature, and that this used was originally moderate. The water intended for the mash is not poured on the malt lying on the false bottom of the mash-tun; for this would have a tendency to force the grain into the perforations, and thus render the draining of the worts from them difficult. To prevent this inconvenience, the hot water is let in between the false and real bottom; thence it rises up through the perforations, floats the grist, and ultimately penetrates all parts of the grain until it rises to the top. The perforations are thus left clear and open; and when the tap is set the liquor flows off quietly, without disturbing the grains, and without suffering any interruption. Mr. Hayman, a modern writer on brewing, declares his opinion, that the second mash-water should not be let in from below: he says it ought to be poured in on the top, but in such a way as not to produce disturbance of the grain. This method, he finds by experience, strains the remaining saccharine matter from the grains more efficiently; and extracts a greater strength than the ordinary mode of mashing for the second time. Sometimes, even when every particular has been apparently attended to with precision, the worts drawn from the mash-tun will not be thin, transparent, and bright. Such worts will not afford so perfect a malt drink as would have been obtained under other circumstances. This defect, in all probability, originated with the maltster. It would appear that the acrospire had not grown sufficiently to permit the conversion of the starch to be completed; hence the raw starch will dissolve in the

worts, will occasion some degree of viscidity, as well as the same imperfect transparency observable in starch made for the laundry. Such worts will have a greater tendency to souring than if they had come off bright and perfectly saccharine. Mr. Collier says, that too low a heat in mashing will afford a wort that does not clear until acidity has, perhaps, set in.

Worts made from pale malt, which, notwithstanding its colour, has been dried in a long continued low heat, are the strongest, will afford the best keeping beer, and of the best flavour. Malt of this kind is the most economical for giving body and real strength, as it has not suffered the loss of any of its saccharine matter by decomposition. Worts drawn from brown malt are the deepest coloured, and are more so than if drawn from malt much more parched: for it is by moderate scorching that the altered principles of the malt become soluble; and, in proportion as they very nearly approach carbonisation they become less soluble. Acerbity of taste will be derived most abundantly from malt parched to a degree a little beyond brownness, but not blackened. This kind of flavour, in some states of the public taste, is required for porter.

But it may be received as a certain fact, that every degree of heat to which the malt has been subjected beyond what is employed for mere drying lessens its actual value as a fermentable substance; and that if deepness of colour or an empyreumatic flavour are acquired by parching, it is at considerable cost to the brewer, and without equivalent value to the consumer. Another advantage supposed to be derived from low drying of malt is the facility of spontaneous clearing in the drink brewed from it.

In concluding this section, it may be necessary to observe, with regard to mashing and grinding, that the opinion amongst porter brewers is, when drink is to be kept long, or when it is to bear a warm climate, that the malt should be coarsely ground, so as to prevent the so-

lution of any but the finer parts, and that the mashing process should continue longer than ordinary to ensure a sufficient penetration.

Section II.

BOILING — HOPPING — COOLING.

When the tap has been set, and the worts are allowed to run from the mash-tun, the transparent liquor is received into a large vessel called the *underback*. This is a mere receiving vessel: no process is conducted in it; but from it the liquor is pumped up into a large copper boiler, which is technically called the *copper*, made sufficiently large to contain and boil each of the lengths drawn from the different mashings. It may be necessary to explain, that by the word *lengths* the brewer means the quantity of wort drawn off from a certain quantity of malt.

As soon as the wort begins to drain out from the mash-tun, it should be pumped up as fast as it flows into the copper boiler without a moment's delay. Worts are naturally prone to acescence, and especially when neither hot nor cold, but at a moderate temperature. It is even proper to adopt means of preventing this evil during the whole time the worts are running from the cock into the underback, if they are not immediately pumped into the copper. To this end a net or hair-cloth bag, containing two or three pounds of hops, is sometimes hung in the liquor contained in the underback; for these, as is well known, are an enemy to the acetous fermentation, but that they are effective in this case is very doubtful. It is necessary, in fact, that there should be two coppers in the brewery, so that while one is engaged in heating the wort of one mashing, the other should be heating water for the second.

Formerly the *copper*, as the boiler is called, was a mere ordinary open vessel for elevating the temperature to 212°. In the present day, it is a vessel made of

strong sheet copper which is close every where but at top, where there is an accurately-fitted metallic valve, opening outwards, and so contrived and loaded that when the temperature rises to 212°, the boiling heat of water*, the steam can find no vent. The temperature, therefore, rises a little above 212°; and does so ever until the effort of the steam to escape becomes an overmatch for the weight with which the valve has been loaded. The steam then pushes up the valve, escapes, and the heat accumulated in the liquor above 212° having been expended in forming the newly-liberated steam, the temperature of the wort instantly falls to 212°, and the loading of the valve shuts it down as before: the temperature again rises, a gush of steam forces its way out through the valve, and the temperature again falls. Thus the heat varies continually, and thus eventually a great portion of the water of the wort is converted into steam; or, in other words, the liquor boils away, which was one of the ends to be accomplished.

Beside the concentration of the worts thus effected by boiling away the water, they undergo a kind of clarification. Worts, let them run ever so bright into the underback, are never so clear as the drink should be when finished; there is always a certain degree of dulness or want of perfect transparency in them, which it is one of the intentions of boiling to remove. In the progress of boiling, if the wort be examined at different stages, it will be soon found that a specimen drawn from the boiler and left a few moments to itself, will appear cloudy owing to the separation of light fine flocks. After further boiling the flocks separate with more facility and in greater quantity, and this is called the *breaking* of the liquor: if time enough be allowed, these flocks subside to the bottom, and leave the liquor quite transparent.

This substance is called *mucilage* by brewers; but it cannot be so, as it is coagulated by heat: it is more likely to be the *vegetable albumen* of the barley.

* We may consider this the temperature of the wort, although it is in fact a little higher. The saccharine matter of the malt elevates the boiling point a few degrees.

In proportion as the worts boil down, vegetable matter, which had been held dissolved in the original quantity of water, now becomes insoluble in the diminished volume: a separation of flocks in this way is also effected, and the quantity increases as the water evaporates.

According to Mr. Combrune, if this sediment be "boiled again in water, the decoction when cold will ferment and yield a vinous liquor. These flakes, therefore, contain part of the strength of the wort: they consist of the first and choicest of the malt and hops, and by their subsiding become of little use." This alone should act as a sufficient warning to avoid long boiling; and it proves that the practice of those brewers who reject this sediment when deposited on the coolers, hereafter to be described, is erroneous.

Were the boiling conducted with free access of air, the consequence would be a much greater formation and deposition of flocks of insoluble matter; for it is known that when vegetable infusions are long boiled under exposure to air, the vegetable matter slowly absorbs oxygen, and is converted into a substance approaching the nature of wood so far as to be insoluble in water; hence it is precipitated. But access of air is not permitted in the brewers' copper; and hence there is no part of the extracted matter spoiled or lost. This is a great advantage of the modern copper, and its value may be appreciated by recollecting the great medicinal power which pharmaceutical extracts retain by having been evaporated in vessels exhausted of air. So detrimental is the effect of ordinary boiling on some vegetables, that such as are possessed of exceeding bitterness are rendered almost tasteless; and this just bears on the present subject as far as the bitter of the hop is concerned.

It may be doubtful, however, if this advantage is not counterbalanced by the equal or greater disadvantages of the close copper. But before the evidence in favour of this supposition can be appreciated, the nature of the hop, an important article in brewing, must be understood.

Hops are the floral leaves or strobiles of a perennial plant, which, as some say, was introduced into England in 1524, but according to Hume about the year 1509. They were brought from the Netherlands, from whence all vegetables used in domestic economy were obtained, even to a salad, a carrot, or a turnip.* The hop is now cultivated in various southern counties of England, chiefly in Kent, Hampshire, and Essex. A mild hop is grown in Worcestershire. The strobiles when ripe are dried by fire at a very low temperature. Their colour should be a pale olive greenish yellow. Very green hops have been gathered too young: when brown, they are either over-dried and have lost their aroma, or they have been allowed to ripen too much on the poles, by which their aroma and bitterness are weakened. Sulphur fumigations are applied to old and ill-coloured hops, as well as to malt, with a view of brightening their tint; but the suffocating fumes of the sulphur discover the fraud. The odour of good hops, especially when they are rubbed between the fingers, is exceedingly fragrant: the hand is left clammy by the rubbing, if the hops are good. In their effects they are narcotic and stupefying, with very little previous exhilaration: their subsequent effect is to produce depression. Hopped beers have the same powers on the animal economy, the narcotic quality of the hop being aided no doubt by the peculiar state of combination in which the alcohol exists. A pillow stuffed with hops is an old and popular remedy for easing pain, and a means of procuring sleep. An over-dose of hops in any form produces headach, vertigo, and slow pulse. The aroma and bitterness of the hop take off the mawkishness of fermented worts; at the same time, as in the case of any other bitter, these qualities have the power of counteracting the acetous fermentation, and thus preserving the beer from becoming sour. Notwithstanding this, the bitter of the hop, dissolved in water, undergoes

* "Queen Catherine when she wanted a salad was obliged to despatch a messenger thither (to Holland or Flanders) on purpose." It was not until about 1547 that edible roots were produced in England. — *Hume's Hist. of England — Henry VIII.*

the acetous fermentation; for malt liquors which have been highly hopped will at length lose all bitterness, and become powerfully acid. The bitter, however, does not always really disappear when by the taste such might have been supposed. Neuman says that it is overpowered, not destroyed; and that alkali will restore it. Others say that all bitters may be readily destroyed even by weak acids.

Shortly after the introduction of hops into England, their use was prohibited by act of parliament, on account of some deleterious quality which was supposed to exist in them. But of late years, legislative enactments have denounced penalties upon the use of any other bitter. It was about the year 1600 that hops came into general use in England; and in 1652, the proper mode of cultivation was for the first time made known in an essay by Walter Blythe.

The fresh hops possess the qualities of the plant in greater perfection than the old; hence one fourth more of the latter, when a year old, is always used as the equivalent of the former by the brewers. It is believed, and perhaps with truth, that heavy pressure and close packing tend to preserve the power of hops when theyare to be kept for a length of time on hands. If not so treated they imbibe damp, and sometimes become mouldy.

It has been stated by Dr. Ives of New York, that the active qualities of the hop do not reside in the leaves themselves, but in an exceedingly fine yellow powder, which may be separated from the hops by beating them well and sifting them. This powder is found in the female hop only, secreted no doubt by the nectaria: the male or wild hop, as not containing it, is never cultivated. Of this powder, about one sixth the weight of the hops may be thus separated. Dr. Ives gave to it the name of *Lupulin,* derived from the botanical name of hops, *Humulus lupulus.* It possesses ten times the power of hops in flavouring and preserving beers.

Dealers in the article value the hops in proportion to the quantity of this powder which they call *condition.*

Analysis showed that lupulin consists of tannin, extractive, a bitter matter, a resin, some wax, and woody fibre. Of these ingredients the bitter principle and the resin are the most important; the former giving the taste to beers, and the latter imparting the narcotic power; for in this resin resides the narcotic principle. The researches of MM. Payen and Chevalier have made known the existence of a volatile oil in addition to the other ingredients of the hop. Dr. Ives had denied the existence of such an oil, although contrarily to the statements of all authors who have written on the subject, and to analogy. The oil possesses the same kind of smell as the hop, but much more intense; and its taste is pungent: it is soluble in a large portion of water. The oil is the ingredient of hops which imparts the aroma to beers, and is an object of the greatest consequence to preserve. By distillation of the hop with water this volatile oil may be obtained. The hop-plant is liable to many diseases: it is of uncertain growth; consumes much manure; gives much trouble to the cultivator; and often returns very little profit. The risk is therefore compensated by a high sale price.

From this history of the chemical constitution of the hop we are prepared to understand how far the brewers' copper is calculated to retain its virtues. It is certain that the bitter of the hop will be extracted and retained; but it is equally certain that some of the aromatic oil will be dissipated and lost. Volatile oils distil over with facility at the same temperature as water. But in the case under consideration the dissipation of a portion of the oil is the more certain as the temperature of the water is frequently above its ordinary boiling degree. Hence a great part of the aroma must be lost in the long continued boiling made use of. Another defect is, that at the elevated temperature of the worts in the boiler a decomposition, to a small but perceptible extent, takes place. There are two substances present, both of them readily decomposable at this degree of heat; one is the saccharine matter of the malt, and the other the

small quantity of the starch which the worts held dissolved. The consequence is, that a certain empyreumatic or burnt flavour is often perceptible on beers, and sometimes it is exceedingly disagreeable.

Were the hops allowed to lie on the bottom of the copper, burning of the hops, and even of the worts, might be in many instances the consequence. In some breweries, in order to obviate this, a vertical rod plunges down the copper, moving tight in a stuffing box at top. This rod terminates in a horizontal bar, carrying an extended chain, called, on account of its duty, a *rouser*. The rod and rouser are both kept in continual motion by connection with the moving machinery of the brewery; and thus the hops are prevented from occasioning any empyreumatic flavour by their sticking to the bottom and burning. Another use of the rouser is to prevent the hops from lying at the bottom when the worts are drawing off, or plugging the cock. The brewer, aware of the loss of heat, and the dissipation of the aromatic oil of the hop, by continued boiling, has added an apparatus for arresting both in their flight. This is the addition of a copper pan of water at the top of the boiler, so constructed that the tube, which permits the escape of the steam and oily vapour, transmits both into the water, and at the one operation heats and impregnates it with the volatile oil. This impregnated water is made use of in the next mashing for taking an extract from malt. Here nothing is gained; for it appears that the oil has already left the wort then boiling, which was the evil to be guarded against. The water in the pan may be thus impregnated with the oil; but when the impregnated water comes, in its turn, as wort to the boiler to be evaporated, the oil is expelled and received into some new water. Thus the oil is continually in circulation, but is never found where it ought to be. The only use in the pan is economy of fuel; the one fire answering for boiling the wort and heating liquor for a succeeding mash liquor. The bitter principle of hops appears to be not very soluble in watery menstrua. The

fact from which the inference may be drawn is one well known to brewers. If too much hops be boiled on a quantity of wort, a pellicle, which has a very bitter taste*, when cooling takes place, will be found floating on the surface. This is the excess of bitter principle which the cold wort cannot hold dissolved. It would also appear, that in a liquid slightly alcoholic the bitter principle is still less soluble. For during the fermentation of wort, even where but a small relative quantity of hops has been used, a bitter matter is thrown to the surface, enveloped in the yest, which also rises, and eventually remains there. Hence yest is always much more bitter than the fermented wort from which it had been obtained; and such is this bitterness, that porter-brewers' yest is unfit for the baker unless it be washed with water. Ale-brewers' yest answers well for bread; but that of the distillers is the best of all. Thus the yest is injured by the presence of what it is a great loss to the beer to have been deprived of, and the brewer annually loses what might produce a considerable income, were the process conducted as I conceive it might be. I have often suggested to brewers that the redundant and lost bitter might be turned to advantage: they have admitted the fact, and left the matter so. The bitter of yest, especially the brown scum of the top, is certainly not the most agreeable part of the hop bitter, but it may readily be turned to good account.

The quantity of hops used for malt-drinks depends on a variety of circumstances, such as quality, the age to which the drink is to be kept, the season of the year, and the climate which it has to sustain. The only circumstance requiring particular notice here, is, that the quantity of hops necessary to preserve the drink against its natural tendency to acetify is greater in proportion to the heat of the weather when the brewing is made. The length of time that it is intended to be kept influences the quantities of the malt and hops, both being increased according as the time is to be long. If the

* Combrune, 205.

drink is to be transported to or through a warm climate the same observation applies.

The Kent, and sometimes the Sussex, hop is strong and pungent; it is on this account preferred by porter brewers. The Worcester hop, being of a milder character and not less preservative, is used for ales; its colour is also paler.

As soon as the different worts have been evaporated sufficiently in the copper, and have extracted all the bitterness from the hops, they are let down into the *hop-back*, which is a cistern with a metal bottom, pierced full of small holes, intended to act as a strainer. The liquor, after having passed through this, is received into the *cooler*. This is a kind of shallow rectangular cistern, consisting of a floor of boards jointed closely, with sides rising about ten inches high all round. It must be set perfectly level, as sometimes the worts covering it are but one or two inches in depth. The area of the cooler is considerable.

The object of employing so large a surface is, that the wort may cool the sooner; the stratum should be so thin that the time of cooling should not exceed twelve hours, lest it turn sour. The cooling is effected by the abstraction of heat from the wort by the vessel, the air, and all the surrounding media, as well as by the evaporation from the surface, which carries away much heat. The cooler is generally at a considerable elevation in the brewery: hence it is not overhung by other buildings that might retard the evaporation, and obstruct the current of air; on the same account, the sides of the building of which the cooler is the floor are constructed as a great louver; that is, with boards arranged in the manner of a Venetian sun-blind.

The use of cooling is to prevent the acetification which would be sure to take place in the wort if allowed to remain even at a high temperature so long as to cool spontaneously. The intention of cooling so rapidly is to avoid that commencement of acetification or souring called *foxing*, which often takes place on the cooler, and is accom-

panied by a disagreeable flavour and odour, with mouldy spots interspersed. When this happens it is sure to proceed in an increased degree, throughout every subsequent stage of the brewing, and during the consumption of the drink.

In order to cool the wort with more celerity some breweries are furnished with long pipes, which traverse a very large quantity of cold water, on the principle of a distiller's worm. Through these pipes the wort is conveyed, and is cooled at once, and the risk of souring is diminished. But this can only be done when there is a great command of water.

In summer, the wort is allowed to cool as low as the weather will permit; and as the coolest part of the twenty-four hours is at a very early hour in the morning, perhaps about two or three o'clock, this is the period at which it is contrived that the wort shall have arrived at its minimum temperature.

At other seasons, the wort is allowed to cool, to the degrees hereafter specified, as proper for a healthy fermentation. If the wort be too warm when the yest is added, the fermentation will run too high; the temperature will spontaneously rise to the degree at which vinegar is formed; and the acetous fermentation will go on simultaneously with the vinous. If the wort be set at too low a temperature, the yest does not take readily nor sufficiently; the drink sickens, it retains a vapid heavy taste, and does not readily become transparent.

In judging of the temperature to which the wort should be cooled, we must consider the nature of the malt, as well as the season of the year. The browner the malt, the lower should be the degree to which the wort should be cooled; hence very pale malt is fittest for summer use, as wort made from it will not require to be cooled below the ordinary temperature of that season.

During the time that the hot wort lies exposed in so thin a stratum on the cooler, there is a considerable evaporation, often amounting to a tenth or more of the whole. This must be taken into account by the brewer

when he is calculating his lengths. No exact estimate can be given of the quantity evaporated, as that must depend on the weather, exposure, and surface.

Section III.

FERMENTATION IN THE TUN.

Under the theoretical consideration of this process, the nature of the changes which take place has been sufficiently described. Here it will be only necessary to point out the practical details of bringing the fermentation to a successful issue.

In summer the wort is to be cooled down as low as the weather will permit, unless it should be below 60°: in other seasons its temperature is to be regulated according to that of the air. Very strong drinks cannot be brewed in summer: in cool weather, strong porter wort, marking 80° or 90° on Dicas's saccharometer, may be cooled down to 58°. Dublin porter wort marks about 55° on Dicas: such may be cooled to 63°, if the total volume be large; or its heat may be a little higher if the quantity be small. The reason of this distinction is, that a large quantity *generates* more heat during fermentation than a small one, provided that the liquor is not diffused over a disproportionately large surface compared with the depth. The degrees here indicated refer to the wort already in the tun, and to which yest is about to be added. This fermenting tun is an immense circular vat or tub bound with strong iron hoops, and covered in at all parts: it is provided with a man-hole door, which may be opened to inspect the process, or to clean out the tun. A certain quantity of yest is then added, and is well mixed up with the wort. In warm weather the yest is not added at once, lest it should excite an unmanageable fermentation. It is usual to let down the worts from the cooler into the fermenting tun, at different times, as soon as they have been sufficiently evaporated and cooled. With each portion, when let into the tun, a part of the whole quantity of yest intend-

ed to be used is mixed, and the fermentation allowed to proceed. It is afterwards fed with small quantities, should such be required: but it will be by far better if the fermentation prove such as will require no such feeding. In cold weather the whole yest may be mixed with the first worts. When the weather is warm, the total yest necessary for any brewing is less than in cold seasons; and for weak drinks less than for strong. When the drink is not required to be much fermented down, as in the case of ales, the quantity of yest should be smaller than when the case is otherwise.

It is to be observed that the higher the heat was at which malt has been dried the less readily are worts extracted from it inoculated by the yest, the more yest will be required, and the more difficult it will be found to induce a good fermentation. For, as has been already explained, much heat alters the saccharine matter as well as the starch and gluten; and any change of these principles is so far detrimental to the new arrangement of their elements, which it is the object of fermentation to induce. These things being understood, the progress of the fermentation is now to be described.

After the mixture of wort and yest has been made some time, a frothy ring is observed leaving the sides of the tun, and proceeding a few inches towards the centre; and this is succeeded by another and another, until at length the whole surface is covered with a thin creamy froth. At the same time a hissing noise, or feeble effervescence, is heard, owing to the breaking of innumerable air bubbles on the surface; and there is a small increase of volume occasioned by involved carbonic acid. Meanwhile, the froth rises higher; at first equally; and at length into abrupt elevations resembling *rocks*, as they are called by brewers. The colour of the froth at this period deepens: at first it was white; next it became yellow; and, lastly, (although it is better if not) it often becomes a brownish yellow. The froth is now highest in the middle of the tun, and the fermentation is at its *maximum*.

At this time the froth has become more viscid; it holds the carbonic acid gas more obstinately involved; the bubbles break into each other and form large ones, which in their turn break, and occasion sudden subsidences in different parts of the foamy head. At length the whole head begins to flatten and subside; the middle part which was the highest becoming now the lowest; and the fermentation diminishes. The viscid head of yest becomes more dense; and having parted with its gas would soon fall down to the bottom of the tun if permitted; but at that period it is skimmed off, and the skimming repeated at intervals as fast as yest appears on it. This is done as well to lessen the fermentation as to remove a certain disagreeable bitterness with which this first yest is impregnated, and which there is a risk of returning to the wort were it not now removed. Some persons, however, skim off the mere surface of the head of yest, and beat down the rest so as to mix. These observations refer exclusively to the brewing of ale; for in this case a low attenuation is not the object: saccharine matter must be left undecomposed; and this will be effected by removing the yest, and preventing its acting too much on the sugar. Not only must ales hold unattenuated saccharine matter dissolved, but they must have the sweet taste of it; and this object is also fulfilled by the removal of the yest, the taste of which is so very bitter. But when the drink under preparation is porter, the indications to be fulfilled are different: the wort is to be attenuated very low, and a certain degree of bitterness is indispensable, greater than in the case of ale, and it may be rougher.

Whilst the fermentation was yet young, the yest thrown up to the surface, if removed, would in a short time fall back into the liquid state. But when the fermentation has been completed, the froth remains as such for a length of time, and has a considerable share of consistence.

On the cessation of the fermentation, if the liquor were left to itself in the tun, the head would all fall to

the bottom; the effervescence would totally cease; the transparency would be restored; and after a short time a new series of changes would set in. A hissing noise would commence; the liquor would again become muddy; a small quantity of gas would effervesce away; the temperature would rise; the bitter and vinous taste would give place to sourness; the smell would become pungent; and, in fine, we should have a vat of vinegar.

To prevent these changes; to conduct the vinous fermentation to a healthy close before the process of acetification has commenced; to retain the sprightliness of the carbonic acid, the exhilarating power of the alcohol, and the aroma, bitter and narcotic influence of the hops; are the objects of the next part of the process.

Section IV.

CLEANSING.

This process is called *cleansing;* and is so named because it partly removes the cause of the foulness or muddiness of the drink incidental to this period. The drink is muddy, because minute particles of yest float through it, and these would continue to do so as long as bubbles of carbonic acid rise from the bottom. The process of cleansing consists in racking off the fermented liquor from the great body of yest into small vessels or casks which are kept constantly full. But as the racking off gives a great check to fermentation, it is the practice of some brewers just before they do so to *rouse* up the wort so as to mix the yest well through it as a last stimulus. In cold weather they even sometimes mix in an additional portion of yest. By the agitation of racking an immense quantity of carbonic acid is slowly liberated, which attaching itself to the suspended particles of yest carries them up to the bung-hole, where both are expelled by thus rising under them. The same effects are also produced by the fermentation which is not yet perfectly extinguished. Yest and carbonic

acid are therefore continually thrown off, the former of which is collected for future fermentations; and the waste from each cask is continually supplied with new drink. By the division of the whole body of the fermenting wort into the small portions contained in the casks, the temperature of each is at once much lowered; and this tends still further to depress the fermentation. In proportion as the carbonic acid effervesces away, the particles of yest, not thrown out at the bung-hole and hitherto rendered specifically lighter by the involved gas, now begin to sink: these constitute the dregs; by the subsidence of which, and the extrication of yest from the top, the drink is cleansed, and becomes transparent. On account of the division of the liquor into small quantities, the fermentation cannot again rise to any considerable height; for it is always proportionate to the total volume; the heat, consequently, is prevented from accumulating, it being commensurate with the volume and energy of fermentation.

Cleansing is generally performed in a number of vessels like hogsheads, called the *rounds*, from which the drink, if porter, is, when sufficiently purged, pumped up into immense store vats, and there kept until required to be drawn off into casks for consumption. In the case of ales the cleansing is accomplished by filling up the ordinary hogsheads or casks, in which the drink is afterwards to be sent out, with the wort when fermented to the proper degree. These casks are ranged horizontally on a long trough, with their bung-holes a little inclined, so that the yest as it rises may run down one side of the cask and be received in the trough beneath for future use. The troughs have holes in the bottom to which conducting pipes are attached: these allow whatever part of the yest falls back into liquor to run through into a proper reservoir; and from this it is returned into the casks. The casks are kept continually filled by a man who carries a leathern hose or tube proceeding from a reservoir of sound bright drink. The hose terminates in a metal pipe and cock;

and by inserting this into the bung-hole he can let in a sufficiency to fill the cask, and so expel the head of yest which floats, and which it is the object to remove. In extensive breweries this is better done by an ingenious self-acting apparatus which fulfils the same intentions, the hogsheads all communicating at bottom by a pipe though which they are all filled to the same height, and supplied as fast as they discharge the yest.

When the fermentation is finished in the casks, and when the drink throws off no more yest, or but very little, the casks are to be bunged down tight, so that the carbonic acid, still generated in small quantity, may be retained by mechanical pressure in the drink, and may impart sprightliness and sharpness. But while in this state in the store they must be occasionally examined, and vent must be given, if there should appear too great a quantity of carbonic acid, lest the casks burst.

The mode of sending out drink in the same casks in which the cleansing had been performed is practised when the drink is ale, or even porter, if intended for bottling, and when it is an object to leave some unattenuated saccharine matter in a state fit for slow fermentation in the bottle. With porter, the more general treatment, when the casks are ranged on the troughs, is to let them discharge the yest, and to collect this for use. When the discharge has almost ceased, the casks, where there is no self-acting apparatus, are turned with the bung-holes downwards: the drink runs into the troughs, from these into the reservoir, and thence it is pumped up into a vat close at all parts, except a small over-fall at the top, throughwhich may flow a small quantity of yest still gradually generated by a slow fermentation which still continues. This vat must, if possible, be always kept full to prevent flatness and souring. It contains a man-hole in the top, with its door, which is made to fit tight by means of paper interposed, and a stratum of sand laid over.

If the weather be warm, or the liquor weak, the cleansing will be finished in a short time; for it is excited to its final effort of fermentation by the warm

temperature. The less the fermentable matter present the shorter will be the period for completing the fermentation. In very cold weather, the process would altogether cease before its completion, and the drink would be dull and heavy. To obviate this blemish, small portable grates of fire are kept burning in the store, or other contrivances are made use of, so as to keep up a moderate temperature.

Instead of the method of cleansing above described another is occasionally practised. The liquor is pumped up from the fermenting tun into a large reservoir, called a jack-back, in which it is allowed to remain until all the yest has collected on the surface, and then it is fit either for vatting or filling into casks; which being bunged, are ready for sending out to the consumer. This practice, however, is seldom adopted.

The use of the process called cleansing is by no means exclusively what the name would lead us to suppose. It is true, that during this process we remove the cause of muddiness from the drink; but we do so by means which are chiefly important because they check the fermentation, and leave the liquor in a condition to maintain itself in a state of soundness, and to protect itself from the approaches of acescency. Racking off, by lowering the temperature and removing the yest, which is the cause of fermentation, checks that process. If this be done just at the period when the energy of the fermentation is naturally a good deal exhausted, the final completion of it may be prevented within the short limit of time during which it would otherwise have been effected; and the uncompleted portion of the fermentation may be made to occupy a much greater length of time. All this is accomplished by the simple expedient of dividing the drink into small batches, so as to lower the temperature, and of removing the yest at a period when the greatest part of the saccharine matter has been decomposed, but not all. If the whole of the saccharine matter were decomposed, the vinous fermentation must totally cease for want of sugar to act on: there would be nothing to prevent the drink (in its usual state of dilution) from

commencing the acetous fermentation, from parting with or changing the nature of its carbonic acid to which its sprightliness is attributable, from losing its alcohol, and from becoming spiritless and vapid. But at the time when the rapidity of the fermentation has been checked, if some undecomposed saccharine matter be left in the drink, the retarded fermentation may still gradually proceed, carbonic acid will be slowly but sufficiently generated, the alcohol will remain unaltered, and the drink will continue to be full-bodied, sound, and well flavoured. These advantages will be still more strikingly manifested if the drink be intended for bottling, or for transportation to a warmer climate.

The practised brewer is well aware of these circumstances. He knows, that if he does not leave some saccharine matter unattenuated, he leaves nothing to feed the drink, nothing to prevent *fretting;* and that although a greater quantity of alcohol may be formed, the drink must want *fulness on the palate.* On the other hand, if the fermentation be checked at too early a period the saccharine matter will not be sufficiently decomposed; a sufficient quantity of carbonic acid will not be generated, and remain entangled in the liquor, so as to give it briskness; the ale will prove mawkishly sweet; it will be heavy; and through the deficiency of alcohol it will not possess the intoxicating quality for which malt liquors are by some consumers valued.

Between these extremes the brewer has to conduct the fermentation, inclining a little more to the former when the article is for immediate consumption, and a little to the latter when it is intended for keeping.

From the observations made it is quite clear that the name *cleansing* expresses but a very inconsiderable part of the use of this process; that its object is not merely to produce transparency in the liquor, but that it aims at the preservation of its body, flavour, and soundness. Were the yest not thus thrown off the rough bitter which one portion of it always contains would be diffused through the drink, and where fine qualities of malt liquors are desired this would be a great imperfection.

Section V.

FINING.

From the process of cleansing, therefore, that of *fining* should be separated. This is merely intended to hasten the deposition of the floating matter that constitutes muddiness. Were the drink* left to itself in a close vessel, for a sufficient length of time, it would spontaneously become transparent. But this would be by the brewer considered loss of time, and therefore of capital; his vessels and storage would be occupied; he would run the risk of the souring of the drink, owing to its weakness; and the equivalent would be that which he obtains without any of these sacrifices. He can make art supply the place of time; and he can clear his drink in a few hours as effectually as in an equal number of weeks, by adding certain ingredients which shall be named after some theoretical considerations.

The theory of this process has never received a satisfactory explanation: the notions of the brewer on the subject are crude and unphilosophical. It is commonly believed that the floating particles are entangled by the fining stuff added; and that the whole is carried down as if by a net, straining the liquor from the top to the bottom.* After some considerations of the subject, and of cases of an analogous nature which occur in other arts, I feel inclined to the adoption of the following explanation:— The particles of solids are held together by the attraction of cohesion. This may be overcome by a superior power: a stone, for instance, may be reduced to powder, that is, its cohesion may be broken down by mechanical force. Each particle of this powder is, however, still a coherent small mass; but the cohesion of these particles may be altogether suspended by pouring an acid on it: the powder dissolves, that is, it is reduced to atoms so small, that our senses take no further cognizance of them. Here the acid acts upon these particles by a chemical attraction, which proves itself superior to the attraction of

* Even Duportal is of this opinion.

cohesion. But if water had been used in place of the acid, the stony powder would not have dissolved, because the attraction of cohesion is more powerful than the chemical attraction of the water to the stony particles. Hence we derive the information that chemical attraction and cohesive attraction are antagonist powers, each counteracting the other; the result of the conflict being determined by the superiority of force on either side. But sometimes the conflict cannot be determined in any decisive way: both forces may be nearly balanced; and both may be exerted with such effect as to produce a modified result, in which the effectual agency of both forces is manifest. Many illustrations of balance between these antagonist forces may be drawn from practical chemistry. Thus, if solution of muriate of lime and solution of carbonate of soda, each of a certain degree of concentration, be mixed, no change for a few moments seems to take place; but then the mixture becomes suddenly opaque and gelatinous. Hence it would appear, that the carbonate of lime has been so far affected by its resumed cohesive attraction as to gelatinise; while that effort is resisted by the solvent power of the liquid, which by its chemical attraction balances the cohesion, and the result is a jelly. A more familiar instance is the following: — When coffee, roasted and ground, is boiled in water, a certain portion of it dissolves, and another portion of it remains suspended in the liquid, neither perfectly dissolved nor perfectly coherent. This portion will not subside for a length of time, because its affinity to the water is sufficiently strong, at a high temperature, to be a precise balance for its cohesion; and hence it remains suspended, retaining just as much cohesion as gives a slight opacity to the liquid. In pharmacy cases of the same kind are common. If coarsely powdered jalap-root or hellebore, ginger or other resinous substances, be boiled in water, the resin is extracted, but not dissolved: the decoction remains opaque. And if coarsely powdered ginger be digested in proof spirit, the resin is extracted, but will

not dissolve: it will remain suspended, no otherwise cognizable than by the opacity which it occasions.

These cases seem not explicable by the similarity of specific gravity between the solvent and matter to be dissolved: such a precise coincidence would be almost impossible to conceive, especially at such different temperatures as they will bear without depositing. Consistently with the imperceptible gradations by which natural operations, like the colours of the rain-bow, are shaded off one into the other without any actual line of distinction, we cannot suppose that there is no intermediate state between perfect solution and perfect non-solution: there may be a state of partial solution and partial solidity. We cannot suppose that these two conditions of solidity terminate abruptly without approximate states of existence. It is quite easy to conceive that the chemical attraction of a liquid may be excited on a substance so far as to suspend its cohesion to a certain extent, although not sufficiently to subdue it altogether. The last effort of cohesion may sustain particles on the last limit of separation, without their being actually separated so completely as to fall into fluidity; and a chemical attraction may subsist between the particles in this state and the liquid in which they are suspended. The following statement given by Berthollet is precisely applicable to the case in point: — "When the solid is reduced into small masses, or is in a pulverulent state, the action by which the liquid wets these small masses may sometimes hold them suspended in it, and overcome the difference of the specific gravity, without producing solution; it is this which is observed in some chemical precipitations wherein the liquid does not regain its transparency, notwithstanding the difference of the specific gravity between it and the substance which it ceases to hold in solution; so that this suspension announces a reciprocal affinity, which retains the two substances in contact, but which is not sufficient to produce solution."

In all such cases, where a substance almost in its state of ultimate division is thus held suspended and attracted

to the particles of a solvent without being actually dissolved, would it not be a very natural conclusion, that in order to produce the separation of the suspended matter, we should either increase the affinity of the solvent so as to occasion solution, or lessen it so as effect the liberation of the solid particles hitherto entangled by chemical attraction. The second of these modes is more easily accomplished than the first. Substances may readily be found which, possessing an affinity for the solvent, will combine with it; and in so doing the balance will be subverted which had previously subsisted between the cohesion of the solid and the attraction exerted towards it by the solvent.

Now, to apply all these facts to the case of the brewer: we find that the fermented liquor is muddy on account of its holding suspended a subtle vegetable powder, supposed to be yest, which although acted on by the affinity of the watery liquor is not sufficiently acted on to dissolve its cohesion. The expedient resorted to by the brewer is to add a substance which will lessen the affinity of the water to the suspended powder by dissolving in the water, and thus rendering it a less effective menstruum: the least possible change in the nearly balanced affinities will be sufficient. The powder thus disentangled will subside by its specific gravity, which previously had been antagonised by the attraction of the water.

The substance used by the brewer is isinglass dissolved in sour beer, the solution being carefully strained through a hair sieve. It should be made of the consistence of thick mucilage. A little of this solution added to the drink will, in a few hours, cause the subsidence of all the suspended matter, and the liquor will then remain perfectly transparent.

I have found that alum possesses the same property. About an ounce of it in powder, dissolved in a hogshead of beer, will soon cause the muddiness to crack; shortly after it will clear, and no taste is communicated by so small a quantity of the salt.

The dried stomach of the cod-fish, called *sounds*, macerated in sour beer, affords a fining liquid equal in most respects to the more expensive isinglass. It imparts no new flavour, if used in a very small quantity. Sometimes the brewer adds the fining liquid himself: in other cases it is sent to the consumer. After being added to the hogshead the drink is allowed a few hours to settle.

To dissolve the sounds in the sour beer perfectly, from eight to ten days are required, and nothing remains but a small quantity of impurities which straining will remove. More or less of this gelatinous solution will be required according as the drink has depurated itself spontaneously or not: a pint, a quart, or even three pints, may be required to the hogshead. But whether we use sounds or isinglass, the less of it added the better it is for the flavour of the drink: much fining liquid of either kind produces flatness of taste, and prevents the drink from carrying a good head. In these respects alum, as a finer, claims a preference; it does not affect the flavour, and it adds considerably to the closeness and creaminess of the head.

It is to be observed, that sounds succeed well only in summer; in winter isinglass must be used.

This fining liquid is of use in another part of the process of the brewer also, and for other purposes beside that of producing transparency. In summer, when the porter has passed through the *rounds*, and has been pumped into the tank in which it is to deposit the last portions of yest, the fermentation often continues there beyond the degree wished for by the brewer. Much fermentation is here dangerous; for the attenuation may be so great as to endanger the soundness of the drink, and the acetous fermentation may set in. In such cases it will be proper to add some fining liquor: for this will precipitate the yest, and will therefore deprive it of that ingredient which keeps the fermentation in activity. This is but another mode of effecting the same object as continually filling up the rounds when the drink is in them

The yest is thus floated out of the bung-hole, and being removed, is prevented from keeping up the fermentation.

The white of egg and the serum of blood answer all the purposes of fining as well as isinglass, so far as producing transparency is concerned.

Section VI.

ATTENUATION.

The same bulk of different liquids will weigh very differently. A pint measure of quicksilver will weigh 13½ times more than a pint of water; and a pint of very strong spirit of wine will weigh one fifth lighter than the same bulk of water. In the same manner a pint of brewers' unfermented wort is heavier than a pint of water; or, in other words, its specific gravity is greater.

When yest is added to the wort contained in the fermenting tun the fermentation speedily commences; and the wort, from being much heavier than its bulk of water, becomes less and less so every hour while the fermentation continues. Why this should be so is easily explained.

Worts are chiefly a solution of a peculiar saccharine matter in water: during the progress of fermentation this saccharine matter is converted into alcohol. Now sugar is much heavier than its bulk of water, and alcohol is much lighter than its bulk of water. It may, therefore, be readily understood, that if we add a quantity of sugar to a gallon of water, a pint of such water will weigh more than if we had added any quantity of alcohol to a gallon of water. Hence it is perfectly intelligible, that if a pound of sugar be dissolved in a gallon of water, and if the solution be subjected to fermentation, so that the sugar is all changed into alcohol, a pint of the liquor so changed must weigh lighter than it did before the change.

From this view of the subject it would appear that fermented wort, as having the saccharine matter changed

into alcohol, must be specifically lighter than water. This would certainly be the case if there were no other soluble matter concerned than pure sugar, and if the conversion of the sugar into alcohol were complete; but neither of these conditions is fulfilled. Wort, beside sugar, contains the matter extracted from hops along with some ponderous matter from the malt; and a quantity of the sugar is always designedly left unfermented. The consequence is that these heavy matters held in solution countervail the lightness of the alcohol formed; and that the fermented wort is much lighter, bulk for bulk, than the same wort unfermented, but never as light as water. This reduction of the heavy wort to a less specific gravity is called *attenuation*, (from *tenuis*, thin,) because, from being somewhat viscid, it is rendered a much thinner liquor.

It is of great consequence to the brewer that he should watch the progress of attenuation, so as to be able to know the precise time at which it should be stopped. The degree of attenuation is the index to the quantity of alcohol formed, to the quantity of unaltered sugar, &c. yet remaining as the food of ales that are to be long kept, and even to the flavour of the drink produced. It is, therefore, obvious of what importance it is that the brewer should possess a means of ascertaining the degree of attenuation with facility. For this purpose, an instrument has for some years past been introduced into practice which communicates the necessary information with tolerable precision and little trouble. It is called a *saccharometer*, (from *saccharum*, sugar,) because it was supposed to measure the quantity of sugar held dissolved in the worts, not only at any stage of or after the fermentation but before it, thereby showing the value or saccharine strength of the wort either on leaving the mash-tun or the copper. It is, however, a bad name, for the saccharometer indicates any thing as well as sugar that adds to the *specific gravity*. This instrument is constructed on the principle of the hydrometer, and is thus derived: —

It has already been explained that a solution of any quantity of sugar in water renders any bulk of that water heavier than a similar bulk of mere water. Any other substance dissolved in water would have the same effect; for instance, salt would do so. It is a familiar fact that salt water is (as it is vulgarly expressed) stronger in floating a heavy substance on its surface than fresh water. Hence it is easier to swim in salt water than in fresh; and it would be also easier to swim in water holding sugar dissolved than if the water were pure. Were there a bath of quicksilver a person's body would altogether lie on the surface, and by no effort could he submerge at once more than a certain proportion of his entire person. When salt is dissolved in water for pickling meat, the common test for fixing the relative quantity of the salt is to add it ever until the pickle acquires such strength as to float an egg; that is, the egg is not to sink to the bottom as it would in mere water; but it is to remain suspended at the top or middle, or any other part of the liquid. From this seems to have been borrowed the idea of the hydrometer and saccharometer; for these instruments are in fact an egg-shaped, hollow, brass ball, and differ only from the use of the egg in being made applicable to the weights of different fluids by a peculiar adjustment. Suppose an egg with a stem proceeding from the larger end, and another from the smaller, with a little weight affixed to prevent oversetting in the water, and you have the instrument in question. If this instrument, made properly of brass, be set in a tall cylindrical vessel of pure water, the egg part will sink; so also will the stem ever until it is almost submerged. But being not entirely submerged, the water stands at a certain part of the stem, and here is made a mark, which mark indicates that any liquid in which the ball and stem sink so far is of the same weight as water, the bulks being alike.

For the brass sinks by its weight, displaces its own bulk of water; that bulk endeavours to recover its place, and does so by pushing up the brass which displaced it,

and it is pushed up ever until the effort of the water (that is, its weight) is balanced by the effort of the brass to sink. The two efforts balance each other; or, in other words, the brass instrument (at least from the mark downwards) and its bulk of water just weigh the same.

But if any thing be dissolved in the water which adds to its weight, it is quite obvious that this increased weight will act more than the former weight of the water, and the instrument will be pushed higher up, and a weight must be put on the top of the stem to sink it to its original depth. This weight may be so adjusted that it will inform us what quantity of matter (suppose sugar) had been dissolved in the water.

The weight may be just so heavy that it will sink in water containing sugar at the rate of a pound or more to every barrel or any other rate. And if a number of weights be adjusted, they will indicate different relative quantities of water and sugar, from very little to very much. This is precisely the principle of the saccharometer; and it is used by adding one or other of the weights ever until the stem sink to some mark in the liquid to be tried. The weight added expresses the quantity of saccharine matter which a barrel of water has dissolved away from the malt in mashing; or it indicates the weight of saccharine matter not yet attenuated in the worts, incorrectly, it is true, as it does not take into account the other soluble parts of the grain nor the alcohol formed; but it gives the mean arising from the heaviness of the sugar, &c. and the lightness of the alcohol, and this answers the purposes of the brewer.

In order to avoid the necessity of such a multiplicity of weights as the different gravities would require, fewer are made to answer by the expedient of using the stem as a scale. This being divided into degrees corresponding to pounds, and the instrument sinking to one or other of these degrees, we see by the weight at top and the degree on the scale, both added together, what the number of pounds of saccharine matter is which the worts contain, with the assistance of a few detached

weights only. Weak worts will be indicated by the scale without any weight added at top.

In the papers presented to the house of commons by Doctors Thomson, Hope, and Coventry, the following instructions are given with a view of remedying the false indications of the saccharometer when used in the common way :—"If it be wished to appreciate the share of the attenuation which is due to the operation of each of these causes, it may be done in the following manner: — first, observe the number of degrees of attenuation which the wort has undergone, and then take a given measure of the wash (or other liquid), note its gravity, and dissipate all the spirit by boiling ; lastly, add to the remaining fluid as much pure water as makes up the original quantity. The gravity which the liquor now has, compared with that of the original unfermented worts, shows the amount of attenuation occasioned by the loss of extract, and compared with that of the wash, shows what is owing to the spirit."

Section VII.

STORING AND OTHER PARTICULARS.

When the drink is finished, it is either sent out at once to the consumer, or it is stored in immense wooden or stone vats, the object of which may be either to keep a sufficient stock to meet a brisk demand, or to allow it to improve in flavour by age, and to become bright. But a chief reason is that summer drink must be made in winter, and held over.

If these objects can be accomplished without any injury arising from souring, they are desirable ; but acetification often sets in, and immense sums are thus lost. It therefore becomes of great consequence to the brewer to obviate this natural tendency of the drink, by all the preventives within his reach.

The first thing to be attended to, is to consider how far the strength of the drink is adequate to its preserv-

ation in store. The weaker it is the more likely to turn sour. Weak drinks should, therefore, be sent out to the consumer as soon as this is practicable.

The next thing to be taken into account is the hopping, and the degree of attenuation. Drink which has been attenuated down to the total decomposition of the sugar has nothing to protect it from acetification but the preservative power of the hops and alcohol; and the quantity of the latter is great in proportion as the drink has been attenuated. If the worts had been originally strong, the alcohol will be sufficiently strong for its preservation, assisted by the hops, which should be used in greater quantity when the drink is to sustain long keeping. But malt and hops are not always used in such quantities, as will ensure soundness when the drink is kept. We must, therefore, restrict the attenuation, in proportion as the quantity of malt and hops has been limited. For by leaving in the drink when finished a quantity of unaltered saccharine matter, we leave a material to sustain the chemical changes which will certainly take place in either of the two following ways,—souring, or slowly continuing the vinous fermentation. It is our business to ensure the latter kind of change; as by doing so we guard in some degree against the former.

We have also to consider whether the shape of the vat may not be a matter of consequence. Every one knows that liquids press in proportion to their perpendicular height, and not in proportion to their volume or quantity. If there be two vats, each containing 500 gallons, one of them being of small diameter and very high, the other of great diameter, and only four feet high, the pressure of the high column of liquid on a given magnitude, say a square inch, of the lowest stratum, would be far greater than that of the low column on a square inch. Suppose, then, that into each of two such vats we pour 500 gallons of beer, the stratum or layer of beer immediately next the bottom will be compressed with much greater force in the tall vat than in the low

one. We have now to consider what is the effect of pressure on beers, and an experiment easily made will afford us full information. Let two bottles be filled with wort in a state of fermentation, and let one be well corked and the other left open. Carbonic acid is formed in both: from one it escapes, but the other confines it, and by so doing such considerable pressure is occasioned, that a very strong bottle is required to sustain it. If both bottles be examined in a few days, the fermentation of the liquor in the open one will be found completely over; but in the other the fermentation will be perhaps but half finished. Hence the saccharine matter was prevented by pressure from undergoing the attenuation which otherwise it would have experienced.

Precisely the same obstruction will be experienced in the 500 gallon vat in which the liquor stands in a high column. Pressure is thus occasioned, the saccharine matter is consequently attenuated much more slowly, the effort tending to acetification is resisted, and the body of the drink is maintained full and sound. Thus the shape of the vat appears to have great influence on the preservation of the drink.

A great means of preventing injury to the drink while in store is the maintenance of a low temperature. Summer is the time of danger, and during this period every minute particular must be attended to, that the danger may be averted. Keeping store in houses covered over merely with a slate roof seems a bad plan: slates, by the darkness of their colour, absorb the sun's rays, and heat the room underneath. A vat sunk to a considerable depth in the ground, as is often practised, keeps its contents at a very low temperature; and if the risk of leakage can be prevented, the plan ought always to be adopted. But in winter the drink kept in such a vat should not be sent out direct as soon as filled into the casks; for it would show to disadvantage. It would be proper to allow the casks to remain for a day or two in a store, aired by fire grates as already described, so that the carbonic acid may readily assume the elastic form,

and the drink appear in good order. Where store is kept under a slated roof the roof should be kept constantly whitewashed, to prevent the absorption of heat.

When the drink has the right degree of viscidity, which a due quantity of malt and a proper fermentation never fail to impart, it always, when poured from one vessel to another, gathers on its surface a close creamy foam or *head,* so that when blown aside, it instantly closes in and collects again. This is more particularly necessary to porter. The low price of porter unfortunately has often prevented the brewer from giving to his drink such a body as would spontaneously carry a close head. It may do so when first tapped in the cellar of the publican; but when the cask has been half emptied, the poverty of the drink then betrays it, and when drawn it no longer throws up a close creamy head. In order to conceal this poverty; the publicans are often furnished with *heading stuff,* composed of solution of isinglass in sourish porter, whisked with a twig ever until it be all converted into a froth. A spoonful of this is laid on the surface. There is a ready method of detecting this artificial heading by blowing on it, and separating it on the surface; if it do not close in immediately again the artifice is suspected. But in order to defeat this mode of detection, the brewer has devised a process that is quite successful: it consists in dissolving two tea-spoonfuls of powdered and dried sulphate of iron (green copperas) in each hogshead of porter. This addition causes a close head on the drink, even when the containing vessel has been half emptied, and is in no degree detrimental: the sulphate is decomposed as soon as dissolved, for its elements cannot remain in combination at this degree of dilution; and even if it were not decomposed, the quantity of a grain and a half to each gallon could not have any injurious quality. The law prohibits this practice. I have found that alum possesses the same property, but less decidedly. It may, however, be observed, that when porter is *well* brewed from *good* malt, and hops used in *due quantity,*

there is no occasion for *heading* or *fining*, or any modifying process.

When beers, whether strong or weak, have grown sour, it is possible to ameliorate them in some degree by proper treatment. The foundation of the process is obviously the employment of some *antacid* to neutralise the vinegar formed; and the only question is, what should direct us in our choice? Caustic alkalies will neutralise the acidity, it is true; but they communicate a saltish, disagreeable taste, and they leave the beer quite *flat*. Carbonated alkalies destroy the sourness and do not cause flatness, as carbonic acid is evolved, some of which remains in the beer for a time. But their defect is that the carbonic acid is generated all at once, and in such quantity that the cask cannot be bunged without risk of bursting. A gradual generation of carbonic acid and destruction of the sourness will be the proper method. This can be produced by marble powder, made a little coarser than sea sand. The quantity to be used in proportion to the volume of drink is a matter of little moment, as no more will dissolve than what the acid will absolutely require to neutralise it; and any excess of marble does no injury to taste or qualities. The hardness of the minute grains of marble obstructs their speedy solution: the neutralisation proceeds slowly and certainly day after day: carbonic acid is generated in such small successive quantities as the beer can readily hold in solution: the whole benefit of the taste of the carbonic acid is retained in the drink which thus acquires the pungency of *high order*, instead of the sharpness of vinegar; and the vessel may be shaken (as it should be every day) without stirring up any white muddiness from the bottom, as would happen were chalk employed. There is one other advantage in the use of marble: when dissolved in the beer by the vinegar present, its taste is rather bitter; and this taste, as corresponding in some degree with that of hops, will be less offensive to the palate than the saltish taste produced by any of the alkalies.

It should be also observed, that nothing injurious need be apprehended from the adoption of this plan.

Calcined chalk has been a *nostrum* amongst brewers for correcting acidity; but this is caustic lime which, as already observed, is deficient of the essential ingredient, carbonic acid.

SECTION VIII.

WATER.

The water of the ocean has a peculiar taste, owing to the solution of various salts; but how it acquired these salts is not agreed on. Aristotle invented the ridiculous and inartificial hypothesis, that its saltness was owing to the scorching influence of the sun. And Tacitus says, that by throwing salt water on burning wood salt is generated by the conflict of opposite elements; which shows that this extravagant notion prevailed for at least four centuries after at Rome: the principle in both is the same. For ages afterwards, the current and very natural opinion was, that as rock-salt is known to exist in vast quantities throughout the world, constituting in some places a great part of the bulk of mountains, and others vast strata beneath the surface of the earth, the waters of the ocean might have derived their saltness from beds lying near or under its bottom. Dr. Halley explained it as follows:—"There is a constant evaporation from the ocean, and a condensation of these vapours in rain over-land: the filtering of this rain through the ground carries with it the salt which it thence dissolves. The accumulation of these land-drain waters constitute rivers; and these run into the sea with a new quantity of salt. The water is again evaporated, and again carries home new quantities of salt. Thus the land is continually deprived of its salt, and the ocean is continually deriving new additions to its contents." Bishop Watson seems to have negatived this hypothesis, by rendering it probable that the quantity of salt contained in

the ocean could not thus have been washed away from the land during a period much longer than the world has been created.

About two centuries and a half since, Bernardine Gomesius proposed a new opinion on the subject. He conceived that the ocean was originally created in the state in which we at present find it, and was as salt the first day as now. This view has one advantage which the former opinions have not: it removes the difficulty of explaining how it happens that such fish as live exclusively in salt water could have lived in the early ages of the world before the ocean had become saline, by dissolving salt away from beds or inlands, a process which must have been slow and gradual. The opinion of the present day is that these waters have not only been salt from the creation, but that they once contained all the other ingredients which were afterwards made use of to form the solid materials of the globe, the whole existing as a chaotic fluid.

Be this is as it may, some waters are much more salt than others: the Dead Sea, for instance, contains nine times more salt than the waters of the Atlantic: one quarter of its whole weight is saline matter: its specific gravity is 1·211. It is certain that any water, however salt, will afford fresh water by distillation.

It is probable that all the fresh water in creation is afforded by a process of distillation on the large scale. From the ocean steam evaporates; this steam is wafted by winds over-land; is condensed in the cold regions of the atmosphere; falls as rain; is received on the earth; is soaked by the earth, and then trickles into reservoirs, or is ready to do so when reservoirs are excavated in the ground. But by lying long in contact with the soil it dissolves certain earths and salts, and then becomes *hard* or *well water*. This, continually filtering through the soil, and finding its way into channels, suffers exposure to the air, which converts it into soft water. By the confluence of these little channels large rivers are formed, which perhaps expand into lakes, or dis-

charge into the sea. The water of rivers, wells, and springs, along with rain and snow water, are, therefore, called meteoric water, and only differ from each other in accidental mixtures.

Water of rivers and springs contains several matters in solution, although in very small quantity: carbonic acid holding a minute portion of carbonate of lime dissolved, common air, and traces of muriates and sulphates have been found in it. The water of the river Clyde, in an imperial pint, contains of saline matter (muriate and sulphate of soda and muriate of magnesia) $1\frac{1}{20}$ grain, silica, $\frac{1}{10}$ grain, and gases $\frac{1}{35}$ of the bulk of the water. The gases consisted of $\frac{1}{20}$ of carbonic acid, and $\frac{18}{20}$ of common air. These gases are the ingredients which render the taste of common water pleasant and lively: when boiled, the taste becomes mawkish, because the gases have been expelled. Well water contains the same ingredients as river water, and owes its hardness to the presence of a greater quantity of earthy salts in solution, chiefly sulphate of lime. The existence of this or any other salt of lime may be detected by dropping in a crystal of oxalic acid, which will produce a precipitate, less abundant as the water is soft.

Springs of fresh water are sometimes found below the bottom of the sea.

The purity of water is indicated by its specific gravity. By a late act of parliament it is defined that a cubic inch of water purified by distillation weighs, at the temperature of 62°, barometer 30 inches, exactly 252·458 grains. An imperial pint of perfectly pure water weighs precisely 20 avoirdupois ounces at 62°. Any water heavier than this must be less pure. That the lightest water is the best is an old and true principle. Pliny says that some judge of the wholesomeness of waters by contrasting their weights. Celsus alludes to the same practice, — "nam levis pondere apparet." Hippocrates thought that the best water is that which heats and cools in the shortest time; and his echo and expositor, Celsus, affirms the same thing. Hoffman informs

us that rivers of a rapid current, or which fall down mountains, afford a purer water than those that are more slow; and hence, he says, that ships coming out of the river Maine into the Rhine draw more water, and sink deeper in the latter, because the waters of the Rhine fall from the highest mountains of the Grisons country.

The chief varieties of water, as far as the subjects of this volume are concerned, are *hard* and *soft* water; and it has been a question on which authors differed, which of them should be preferred for brewing. "Great differences," says Neuman, "are observable in waters in regard to their fitness for brewing. It is remarkable that the waters of rivers, and of stagnant ponds that are not putrid, though quite muddy and unfit for drinking, and even disgustful, produce better beer than those of the finest and most limpid springs. Perhaps it is their softness that adapts them to this use, whilst their impurities are separated in the course of the fermentation." By some we are cautioned never to use hard water, it being, as they affirm, totally incapable of taking a complete extract from malt and hops, as it is well known to be (say they) from tea or from meat. Others affirm that hard-water worts do not ferment well, and that they afford a weak vapid beer. It is difficult to conceive how the existence of two or three grains of saline and earthy matter in a pint of water could, even in the most trifling degree, influence its solvent power on the materials used in brewing. The matter of malt which partakes so much of the nature of sugar, cannot be conceived to dissolve less readily in such water than in the softest. And as to the bitter principle of the hop, one would be inclined to suppose that it is not different from all other bitter principles: wormwood, gentian, quassia, and colomba, give out their bitterness freely to water containing salt, dissolved in very large quantity. This is well known. And what in itself is ample demonstration on the subject is, that the grains and hops left after they have been duly infused in hot hard water, repeatedly applied, are found to be perfectly exhausted of their qualities.

As to the taste of hard water, provided that it has no accidental impregnation of contiguous impurities, there can be no reasonable objection. Were its peculiar taste retained after boiling, it is so exceedingly feeble that it must necessarily be covered by the bitter of the hop. But by the boiling which it undergoes it is brought nearly to the state of soft water: its carbonic acid and common air are disengaged, and its difficultly soluble earthy salts and substances are precipitated.

On the whole, it appears that the objections to hard water originated in the distrust natural to mankind in matters which they do not understand. The nature of hard water was not known to brewers of former times: the cause of hardness being not palpable to the senses, it became a fair subject of conjecture, and prejudice became hereditary.

In short, reasoning on this subject is of little use when we have proof derived from the most extensive experience. The soft water of the Thames was once supposed to be superior to all others for brewing malt liquors. Dr. Irvine says, "Sometimes common salt is added to the water used in extracting the sweet matter of malt, with a view, as may be supposed, of exciting thirst; but it produces some other effects; in particular, it moderates the fermentation, makes the liquor fine and seems to be the cause of the great superiority of the water of certain places in producing fine malt liquor. The water of the Thames is much celebrated on this account, and it contains a little salt; and in most places remarkable for fine malt liquor I have found this also to be the case. No advantage will be obtained if the quantity of salt be so great as to be discovered by the taste."

So much the reverse of pure is the Thames water that we find it stated in the Philosophical Transactions, 1667, that in eight months' time if kept in a cask it "acquires a spirituous quality so as to burn like spirit of wine." It will also become fetid, and if then agitated will soon after let fall a "*black lee.*" Inflam-

mable gas is therefore formed in it, and it is this which takes fire.

Yet this boasted superiority of the Thames water has not continued to ensure a preference for it; and it is now almost entirely superseded either by hard water, or by the New River water in the great London breweries. It is known that between a stratum of clay and a stratum of chalk, about 200 feet below the foundation of London, there is a never failing supply of excellent hard water. The supply for each brewery is obtained from pumps sunk in wells excavated to the necessary depth. This fact seems decisive: London porter is a sufficient proof of the adequacy of hard water to answer all the purposes of the brewery.

However, be the water of what kind it may, it is certain that it should not contain putrescent vegetable or animal substances. Neuman says, "When waters used for brewing have received an impregnation from the carcasses of animals, though so slight as not to be perceived on the water itself, as soon as the liquor has been brought into fermentation, the putrid ferment has exerted its activity, and disposed the fermentation to its own kind."

It is so great a convenience to the brewer to have a plentiful supply of water on his concerns that large sums are often expended in sinking wells for obtaining it. The water thus procured has often the ill smell and taste of sulphuretted hydrogen; but it is not the less fit for use; for by boiling, or better, by exposure to the air, both of these defects are removed.

But caution is required in the use of some waters, although rarely. In an early volume of the Philosophical Transactions we find the following account:—Near Dantzic there is an inland sea made by the meeting of three rivulets and the water of some springs. The adjoining soil seems to be sand mixed with clay. It is stored with wholesome and delicate fish, and the water is sweet and salutary. But during the three summer months, every year, it becomes green in the middle. If

this water and its green matter be swallowed by cattle, dogs, or poultry, it causes certain and sudden death.*

Section IX.

COLOURING MATTER.

The epicurism of consumers of malt liquors is such that not only must the sense of taste be gratified in all its capricious varieties, but even that of sight must not be neglected. Sometimes the drink is valued for being almost as pale as water; sometimes it is to be amber-coloured, sometimes brown, and formerly it was the *ne plus ultra* of perfection to be nearly black.

It has been already observed that the more slowly the malt has been dried, and the lower the temperature at which the drying has been effected, the paler its colour will be, the greater the quantity of saccharine matter it will contain, and, *cæteris paribus*, the stronger and paler will be the worts afforded. On the other hand, a high quick heat will parch and brown the malt, will replace the saccharine taste by one that is austere and subacid, will produce brown worts, deep in proportion to the degree of heat and its continuance, and the worts will be weak in proportion as they are brown.

These positions once understood, it is easy to appreciate the effects of colour on the flavour and value of malt drinks. The injurious consequences of high-drying the malt are now so well understood by brewers that they have discontinued the practice of drawing their extract from brown malt; and in place of it they employ a malt prepared by charring, in such a manner as to become in a great measure soluble in water. For the preparation of this malt a patent has been taken out. Its use is not to contribute any thing to the strength of the worts, but to impart colour and a certain flavour. Dr. Thomson has made the following observations: — The essential difference, he says, between ale and porter

* Abridgment by Hutton, &c. vol. i.

is that the latter has a deeper colour, and an empyreumatic taste. Colour and flavour were originally obtained by mixing with the pale malt, used for ale, a proportion of malt dried at a somewhat higher temperature, and being thus slightly scorched it is rendered capable of communicating to water a deep tan colour, and a peculiar flavour. In the composition of the best porter, two parts of brown malt and three of pale are made use of. The price of the former is generally seven eighths of the latter; but its proportion of sugar, according to the highest estimate, is not above half that afforded by the pale, and perhaps it is on an average but one fifth. Even if it be one half, the brewers are paying a fifth of the entire cost of the malt for colour and flavour. The price of this brown malt has of late years increased so enormously that Spanish liquorice, burnt sugar, &c. are used for colour and flavour; or else the strength of the liquor is diminished, rendering it liable to sour by keeping; for the alcoholic strength is compensated by *cocculus indicus*, or other narcotics. This diminution of alcoholic strength drives the lower orders to the use of gin and opium; and the frauds on the revenue have absorbed all moral feeling on the subject.

The inventors of the patent malt have discovered that by exposing common malt to 430° in close vessels it acquires a dark chocolate-brown colour, and it is rendered so soluble in water, hot or cold, that when mixed with $\frac{1}{10}$ part of pale malt it communicates to the worts the perfect colour and flavour of porter. By employing four parts of pale malt with $\frac{1}{20}$ of patent a stronger liquor may be obtained than from the usual proportions of three parts of pale malt and two of brown.*

Here, however, it may be observed, it is the opinion of some skilful brewers that the old high-dried malt imparted the porter flavour more agreeably than the patent malt, and that burnt sugar is not inferior; but the latter is prohibited by the excise laws. The patent malt is used in the copper, in the mash-tun, or in both. Seven

* Annals of Philosophy, x. 465.

pounds of it are sufficient to colour fifty barrels of table-beer; now that this beverage is, at least in Dublin, fancied for being pale.

Beside the colour communicated by the parched malt, it is obvious that the hops contribute some, especially those that are brown. Formerly the colour was aided by a variety of substances,—as elder-berry juice, treacle boiled down to blackness, parched flour, &c.

Formerly, when a deep colour was given to porter by a large quantity of brown malt a proportionate empyreumatic austerity of flavour was also communicated, which then was relished, but would not be endured in the present state of the public taste. In the patent malt, the saccharine matter is altogether sacrificed to colour, and the less flavour communicated by it the better; for the qualities of ale are now expected from porter. In the present day, porter is expected to be soft, full, somewhat sweetish, brisk, and without any empyreuma. Ale should contain the finer parts only of the malt in solution; it will be the better if but one extract have been taken. The hop used for ale should be the mildest Worcester growth, and not the pungent Kent hop proper for porter. The strength of the wort for ale should be much greater than for porter; and the taste of the finished ale should be sweeter, and the colour paler. These are the differences between ale and modern porter.

Section X.

PROCESSES FOR BREWING PARTICULAR KINDS OF MALT LIQUORS.

Hitherto the general principles which should direct us in the brewing of all kinds of malt liquors have been entered into without reference to particular processes. It now remains to describe the method of obtaining the different kinds of malt drinks that are chiefly in use.

Porter.

This liquor was first brought into extensive use by the success of the London brewers, who for a length of time had the almost exclusive manufacture of it. Indeed it was then universally believed that no other water but that of the Thames could produce it in perfection; a delusion since removed by its being made equally well in all parts of the United Kingdom, if the brewer will use proper ingredients and in sufficient quantity. About the beginning of the eighteenth century a malt liquor called *entire butt* was much in use; and afterwards a variety called *brown stout:* these were heavy strong drinks; and about the middle of the eighteenth century they began to give place to a liquor the brewing of which was then much improved, and which happened to be, as Malone informs us, in great request amongst the street porters of London: hence it obtained the name of *porter.* In some years after it became one of the necessaries of life, and has continued so ever since.

The manufacture of porter has been subject to all the changes which the capricious taste of the public could devise. At first it was requisite that it should have a heavy taste, and a blackish colour; but this kind being reported to be unwholesome, and apt to occasion dyspeptic symptoms, it was conceived that to give it age was the remedy: but the liquor being not strong, age was sure to produce sourness in a slight degree, or *hardness,* as this is technically called. The secret of inducing sudden old age on an infant brewing of porter was soon found out; and the method of making best old London porter, in a fortnight, was to mix porter that had become sour, in a certain quantity, with fresh drink. At length the publicans were let into the secret, and they were furnished by the brewer with two separate hogsheads, one of sour, the other of fresh drink. Finally, so notorious was this practice, and so barefaced the imposture, that in all public-houses hydraulic engines were fitted up, through the pipes of which, by the combination

of two or three pumps, drink of any age required could be brought out of the cellar ready made. At present the public taste has undergone a new revolution, and nothing but a full, sound, fresh, dark-coloured porter will be relished.

In no respect have the public suffered more severely by the whimsicality of taste than in the instance of porter. It is absolutely frightful to contemplate the list of poisons and drugs with which this beverage has been (as it is technically and descriptively called) *doctored*. Opium, henbane, *cocculus indicus*, and Bohemian rosemary, which is said to produce a quick and raving intoxication, supplied the place of alcohol. Aloes *, quassia, gentian, sweet-scented flag, wormwood, horehound, and bitter oranges, fulfilled the duties of hops. Liquorice, treacle, and mucilage of flax-seed, stood for unattenuated malt sugar. Capsicum, ginger, and cinnamon, or rather cassia buds, afforded to the exhausted drink the pungency of carbonic acid. † Burnt flour, sugar, or treacle, communicated a peculiar taste which many persons fancy. Preparations of fish, assisted in cases of obstinacy with oil of vitriol, procured transparency. Beside these, the brewer had occasionally to supply himself with potash, lime, salt, and a variety of other substances, which are of no other harm than in serving the office of more valuable materials, and defrauding the consumer. After the continuance of these abuses for a length of time, the legislature interposed, and at present the brewer is bound by an oath against the use of any thing but malt and hops.

The qualities which constitute good porter in the present day are perfect transparency, a light brown

* During the first four years that the Cape of Good Hope was in possession of the British more than 300,000 pounds of aloes were imported into England. How could such a quantity be consumed, except, as Mr. Barrow states, by the London porter brewers? — *Paris's Pharmacol.* ii. 229.

† It appears that some of these aromatics communicate a much more powerful taste if added before than after fermentation. Neuman affirms that as much powder of nutmeg as will lie on the point of a knife gives a flavour to a large vat of fermenting beer, whereas after the fermentation is finished the quantity to which it gives a like impregnation is comparatively inconsiderable. Spiced ales were once highly in esteem.

colour, fulness on the palate, pure and moderate bitterness, with a mixture of sweetness, a certain sharpness or acerbity without sourness or burnt flavour, and a close creamy head, instantly closing in when blown aside.

The following formula will afford excellent porter: — For every hogshead of keeping drink, or a hogshead and and a third of drink for speedy consumption, the ingredients, when the thermometer stands at 55°, may be used in these relative quantities: — the grist, in all twelve stone, should consist of a stone and a half of amber malt, a pound and a half of patent malt, (that is, malt resolved into mere colouring matter by charring,) and all the rest is to be pale malt. The quantity of water for the different mashings, if the porter is for immediate use, and a hogshead and a third is to be produced, should be such that the gravity of the worts on Dicas's saccharometer will be 55 pounds per barrel, when all the worts are mixed. In summer, three pounds of best Kent hops will be required; but in winter, a quarter or half pound less will answer sufficiently well for preservation. If the drink is to be brewed for keeping, the quantity of malt and hops must be increased in proportion to the time.

From the foregoing estimate of the quantity of porter producible from certain weights of malt and hops must be deducted a loss which occurs during the several stages of the process amounting, the whole year round, to about five or five and a half per cent., on drink sent out as soon as finished.

Ale.

Ale in the present day does not differ from porter so much as it formerly did. Ale is of a lighter colour; it is stronger, sweeter, and is less hopped than porter.

In order to make a strong keeping ale of an excellent quality, the following should be the proportion of the ingredients: — Forty bushels of best pale malt and fifty pounds of hops. For the first mash, ten barrels of water at 172° may be let on and raked for half an hour,

and then allowed to stand for an hour. Water at 180° may then be leaked or let on so as to run through the malt, and to wash away all the wort soaked in the previous mash. These two liquors, when boiled down with the hops, fermented, and finished, ought to produce eight barrels of ale at 100 pounds' gravity on Dicas's saccharometer. But in the one mash the malt was by no means exhausted of its saccharine matter, although what remains is not of so fine a quality as what had been dissolved away. The same malt and hops will, however, answer extremely well for making table-beer; and with this intent a second mashing may be made with water of 185°, and even a third with water of 190°; the quantities being such, that after boiling on the same hops, fermenting, and finishing, there will be twelve barrels of beer at thirty pounds' gravity.

An inferior, but yet a good ale may be made from forty bushels of prime pale malt, and thirty pounds of good hops. The mashing heat may be as before, and it may be calculated as before to produce both ale and beer. In this case, twelve barrels of ale at seventy pounds' gravity, and ten barrels of beer at thirty pounds, will be produced. Or, if the object is merely to obtain ale at seventy pounds' gravity, the quantity producible will be fourteen barrels.

If table-beer of a good quality, without any ale, is required, the quantity of materials to produce thirty barrels of finished beer should be, malt forty bushels, good hops twenty-five pounds, as much water as will produce about thirty-five barrels of hopped wort; and this will finish about thirty barrels of beer.

In calculating the quantity of water necessary to produce a given quantity of a first mash it will be of use to know that an imperial bushel of ground malt absorbs and retains about $6\frac{1}{3}$ imperial gallons of water.

Section XI.

DOMESTIC BREWING.

It would be a great mistake to suppose that in order to brew good ale it is necessary to have recourse to the complicated and expensive apparatus of a regular brewery, or to act with the large quantities in such places made use of. On the contrary, reasons will be hereafter assigned for believing that the best ale can be obtained on the small scale. And I can speak from experience, that better ale than can readily be purchased may be brewed with an apparatus, the first cost of which would not exceed one or two pounds.

To describe a cheap apparatus for domestic brewing, which will nevertheless afford excellent keeping ale or table-beer, will not be the least useful object of this treatise

A common porter barrel should be procured, one end of which is to be taken out and converted into a false bottom, by letting it rest on a hoop nailed round the lower part of the barrel, within three inches of the real bottom. This false bottom is to be perforated with a vast number of gimlet-holes. Between the real and false bottom, a cock is to be fixed in one of the staves of the barrel. This is the mash-tun. Another porter barrel, with one end taken out, will be a convenient fermenting-tun, and it may be placed beneath the cock of the mash-tun, so as to receive the wort when it is drawn off. In this position it serves also as the underback. A tin-plate boiler may be procured, in the bottom of which is a cock; and the insertion of the cock may be covered over within the boiler with a tin-plate colander, which will permit the boiled wort to strain off, but will detain the hops. This boiler may fit on a common fire-grate. It will answer, also, for heating the mash liquors. A thermometer may be used, but it may be done without, and the proper heats determined bv mere measurement of cold and boiling water.

Fifteen gallons of boiling water are to be thrown into the mash-tun, and five of cold water (60°). The temperature of this mixed water would be 174° but for the cooling influence of the wooden vessel, which, however, should have been well scalded immediately before. The mash-water will prove to be about 170°. Two bushels and a half of the best ground pale malt are now to be quickly shaken in, while a second person continually blends the malt and water with a stick. The agitation is to be continued for half an hour, the barrel being kept covered with some folds of thick linen cloth, which will readily permit the agitation of the stick. After an hour's repose, the cock may be opened, very little at first, but more by degrees. The wort runs bright and clear; and the original twenty gallons come off less by the soakage, which amounts to so much as seventeen gallons. Just when the last portions have run off, water, not quite boiling, is to be lightly let over the residual grains, to the amount of twenty gallons, and allowed to percolate through so as to wash down the wort which had been retained. The total amount of wort obtained may now be about twenty-three gallons. The wort is then to be boiled with about three pounds and a quarter of best mild hops, for twenty minutes: after which it is to be drained off into the fermenting tun; and when it has cooled nearly to blood-heat (98°) about a quart of good yest is to be mixed in, and the fermentation is to be continued until completed. In cold weather, the tun, while working, must be kept in an aired apartment, or near the fire, as on this small scale it does not maintain its original temperature; and unless this is done, the attenuation will not be by any means sufficient. When the fermentation shows a decided tendency to go down, although a moderate warmth has been kept up, the liquor is to be racked off from the fæces, and put into a cask. The ale will measure twenty gallons. It should be closely bunged up; and it will be excellent in about month.

Having passed some time in Wales, during the sum-

mer of 1829, I was much struck with the excellent quality of the ale of that country. On making enquiry of those who made it I could find nothing peculiar in their process, except that they brewed medium quantities at a time, that they used good malt and hops, spared neither, and took but one extract from the malt. The proportions were as follow, the bushel being equal to forty-two imperial quarts:—From ten bushels of the best amber malt, 110 to 120 imperial gallons of wort were drawn at the one mashing; and for this quantity of malt fifteen pounds of hops were made use of. The ale was full-bodied, rich, and sound: if it had any fault it was, perhaps, a little too bitter. The bitterness had the good effect of permitting the ale to get age without injury, and with great amelioration of its quality.

The residual malt and hops may be made to furnish common table-beer, by taking off another mash from the malt at 190°, that is, water somewhat under the boiling temperature; boiling the wort on the hops, and conducting the fermentation as before. Table-beer is a weak ale, and it may be made of the same quantity of malt and hops, and in the same manner, using as great a quantity of water as may be desired to reduce its strength to any degree required.

Ale thus brewed for domestic purposes needs no artificial process for clearing: it will spontaneously become transparent, and excellent in every quality. It may be bottled with particular advantage; for the small total quantity fermented will not have generated so much heat as to run down the attenuation very low. It retains good body, and the unaltered saccharine matter is sufficient, in quantity, to permit a slow and long-continued fermentation in the bottle; during which it becomes mellow to the taste and highly vinous. It may be kept in bottle without risk of forcing out the cork or bursting the glass: this quality is attributable to its strength. Weak ales undergo a much more violent and unmanageable fermentation than strong ones: hence table-beer in warm

weather will burst the bottles, while strong ale will not be affected. It is to be observed that table-beer should have the characters of an ale, not of porter.

For making excellent ale or table-beer it is not absolutely necessary to use malt. To conceive this subject rightly, we must consider that it is the sugar of the malt which undergoes fermentation, and that any other sugar will ferment just as well, although no other sugar is so cheap. Economy and long habit have established malt-sugar as the brewing material; but cane-sugar will afford an excellent drink. To persons residing in the country and far from breweries, as well as to those who do not choose the great trouble of managing malt, this is a valuable fact. Another advantage of cane-sugar is that the apparatus necessary for converting it into beer is much more simple: all that is required is a cask which has no bung-hole, or has it well stopped up. This is to be set standing on either of its ends: a cock is to be fixed in one of the staves, about an inch above the bottom chimb; so that in drawing off the liquor the sediment cannot also run. In the centre of the top of the cask, that is, in the centre of its other end, a hole is to be bored of such size as will admit a large bottle-cork. Let us suppose that the cask holds ten gallons, and the drink is to be tolerably strong ale.

The proper quantity of hops required for ten gallons of ale in this process will be about a pound and a half. On this quantity contained in any convenient vessel pour on eleven gallons of boiling water, or what is much better, boil the hops in the water for about five minutes and no more; then strain off the hops: in the strained liquor dissolve fourteen pounds of sugar; and mix in a pint of yest of the best quality. Pour the whole into the cask: it will soon begin to ferment: it will throw up its yest through the cork-hole at top; and this being retained within the external rim of the chimb, it will for the most part fall back into liquor, and run back into the cask. It will require, at the ordinary temperature of summer, so much as three weeks or a month to com-

plete the fermentation. For the last fortnight the cork may be generally kept in the hole; but it should once every two days be removed to give vent to the fixed air, and then replaced. When the fermentation appears at an end, the taste of the sugar will almost entirely have disappeared, it will be barely perceptible. The cork may then be permanently driven in, and in four days the ale will be fit for draught or for bottling.

As to the quality of the sugar it is a matter of little consequence: white sugar will afford an ale scarcely coloured: brown sugar will impart proportionate colour, and not quite so pure a flavour. Should colour be an object, it may be communicated by the raspings of an overbaked loaf, or by scorched treacle; but this is matter of little moment. The drink will spontaneously fine itself.

To persons who have acquired an inveterate predilection for the abominable and varied flavours which the *skill* of the brewer enables him to communicate, this pure and simple drink may be less pleasing; but it is singular how soon the consumer acquires a high relish for it, and prefers it to every other. There is a purity of taste belonging to it quite different from the indescribable jumble of tastes so perceptible in common ales, and a light sharpness combined with tenuity, which is much more agreeable than the glutinous or mucilaginous softness of even the best ales. But it has one advantage which places it above all competition, and that is its lightness on the stomach: this when compared with the sickly heaviness of malt-ale is really remarkable. The whiter the sugar the lighter will be the ale; and age greatly conduces to the same end, provided that the drink is sound, which is best ensured by bottling.

Hops are by no means the only bitter which may be made use of for preserving and flavouring such ales; others can much more conveniently be procured in certain situations. Mixtures in various proportions of wormwood, powdered bitter oranges, gentian root, and rind of Seville oranges, will afford an excellent bitter, perhaps more wholesome than hops, and, if skilfully

combined, to the full as palatable: in this position *the brewers cannot refuse to bear me out,* for reasons with which many of them are acquainted. Gentian, and particularly quassia, must be used sparingly; for the bitterness of these is of so lasting and penetrating a kind that much of it is sure to be disagreeable.

It has been shown by M. Dubrunfaut that a good beer can be produced from potatoes: the potatoes are to be grated to a pulp; this is to be well mixed with boiling water, and ground barley-malt is to be added. The liquid being drawn off is to be hopped in the usual way, yest added, and the fermentation induced. The beer thus produced, after being bottled, was found greatly to resemble Paris beer.

In certain parts of Ireland an excellent beer is brewed from parsnips by a process somewhat like the foregoing, except that no malt is used: the bitter employed is hops In short, malt is by no means necessary to the production of wholesome and agreeable beers.

It may be here expedient to give some practical rules for bottling all sorts of ales; a process very often misconducted in domestic economy.

The first question to be considered is, whether the ale is in proper order for bottling? If on drawing out the vent-peg of the cask the liquor spurts up with force it is a proof that the fermentation is still too active to render it safe to bottle. The best way of proceeding in this case will be to fill up the bottles and to leave them uncorked for twenty-four hours. Should they have lost by frothing over, or should the froth have subsided in the bottles, they are to be filled up within two inches of the corks: the corks are then to be driven home, and the bottles are to be laid on their sides. The use of laying them on their sides is in order to soak the corks and swell them so that they may fit perfectly tight, and thus totally prevent the escape of carbonic acid; for it is to the presence of this gas that the briskness is attributable. It is also possible that when the bottles lie on their sides they offer less obstruction to the last feeble

efforts of fermentation than if they stood in the high column which an upright posture would produce. Pressure resists chemical changes.

In this state the drink becomes *up* in the bottle, as it is termed. If it be strong, it remains quiet; if weak, it begins to burst the bottles; and as soon as notice of this kind is given by one bottle, all the rest should be set standing up: this will prevent further bursting. In winter the bottles must be kept moderately warm; in summer, cold.

But if on drawing the vent-peg from the cask the liquor appears quite still, its taste should be examined. If it is still a little saccharine, and has a little briskness, it is just in order for bottling; and the bottles when filled need not be left uncorked for any length of time. If the drink appears vapid and acidulous, it is totally unfit for bottling.

Home-brewed ales made in small quantity and in cold of winter do not succeed well for bottling. The temperature is apt to fall in the tun before the attenuation is completed; the yest then subsides; the drink is drawn off into the bottles, and being now destitute of yest, scarcely any fermentation continues. There is little alcohol formed, and hence the drink does not keep. All this would be prevented if the heat of the tun were kept up by artificial means, until a good attenuation had been obtained.

Section XII.

OBSERVATIONS ON THE PRESENT STATE OF THE ART OF BREWING.

To conduct a brewing, on the large scale, to a successful issue, and to obtain the best produce, as to quality and quantity, from a given portion of materials, is certainly a work of some difficulty and hazard. The difficulty is, however, not of such magnitude as the brewer supposes, or would lead the world to suppose. The brewer often deceives himself into the belief, that

he is in possession of secrets of his art which are of transcendant importance. He knows that by their application he can brew good drink; but he is not aware that by other methods he might produce as good or better. He fancies that he has fixed with wonderful precision the epochs in each process at which the most perfect results are obtained; and the knowledge of these he preserves with jealous secrecy, as the *ultimatum* of research. Yet there are few arts in which experience affords so little real knowledge, or in which mistaken principles are more likely to be adopted; and for a very obvious reason. To make experiments in brewing on the large scale is a dangerous occupation of capital. No brewer ever thinks of making such an experiment if he apprehends a failure: when untoward circumstances occur in a brewing, his object is very naturally to correct and modify them, rather than to ascertain what would be their results if allowed to proceed as they threatened. On the small scale nothing can be learned, as the results are so very different. Throughout his whole career he is cautious, and never willingly varies from that *norma* which he has once found successful: hence the results of other modes of operating are known chiefly by conjecture; disputed points remain for ever matters of opinion, and, in fine, the art remains pretty much what it was a century since.

Some of the difficulties with which the brewer is embarrassed seem to be of his own creation: not only the magnitude of the scale on which he works is productive of these ill consequences generally, but in detail leads to results still worse.

In the working of a large tun of wort there is often great risk of running the whole into the acetous fermentation. The heat spontaneously produced by the chemical changes which take place in so large a quantity of matter is considerable, and this, aided by the occasional excessive heat of the weather, renders the process sometimes unmanageable. Besides the risk, or the actual occurrence of sourness, there is another ill consequence

which may be apprehended, and that is, the too great attenuation which an ungovernable fermentation may produce.

The injury which results in this case, if sourness be avoided, is poorness, or want of fulness on the palate. It is certainly true that in proportion to the degree of attenuation alcohol is developed, and the liquor becomes more intoxicating; but it also becomes a dead bitter without the modification or *relief* of flavour produced by the simultaneous sweetness of the saccharine matter, some of which should have remained unaltered. Drinkers of malt-liquors do not value them, whether ales or porters, for being alcoholic, so much as for having a certain flavour. In proportion as alcohol is evolved, the sugar disappears; the mucilaginous viscidity of the liquor, which depends on the presence of sugar, is lost; and this once lost, the drink can no longer retain and envelop the carbonic acid which ought to be present to impart briskness, sharpness, and creaminess of head. The abstraction of all saccharine matter is the abstraction of that food on which the liquor should live and feed during the time that it remains with the consumer; and deprived of which, it will feed on its own body. Such liquor will not keep unless it originally contained more fermentable matter than it generally does: it will soon become sour, and leave no desirable quality behind.

These injurious consequences arise from over attenuation: this results from excessive fermentation; and this again from too great a total volume of acting materials, aided, perhaps, by heat of weather. The injury is as severely felt as it is universally acknowledged; and yet no attempts are made to adopt a remedy, although such will present itself after very little reflection. Instead of fermenting a large quantity of wort in one tun, let the whole, as soon as the yest is well mixed, be divided into several small ones, and the end is attained by means as simple as effective. The consequence of this proceeding will be, that as the quantity of each batch of liquor is small, the quantity and intensity of

chemical action will be small; and the quantity of heat, in other cases spontaneously developed, will in this instance be null. There is this essential difference between the phenomena of fermentation on the large and small scale: — on the large scale the temperature rises continually from the degree at which the worts are set; on the small scale the temperature continually falls. This being the case, it is obvious that as the intensity of fermentation is increased by elevation of temperature, so it will be restrained by diminution. We, therefore, derive this important advantage from fermenting small quantities of worts, that the attenuation is urged to a less extent, a greater quantity of saccharine matter remains unaltered, and the liquor, while in the cellar of the consumer, will not fret into vinegar for want of some fermentable matter on which the tendency to chemical changes can exert itself. In this way the fermentation may fearlessly be conducted during the warmest weather without risk of *foxing;* and the brewer need not hesitate in any weather to use the quantity of yest necessary to the excitement of a healthy and energetic fermentation, such as will secure his beer against sickliness and heaviness of taste. There would be no more trouble in this method of fermenting, on account of racking off from a number of small tuns, than there would in the case of one: they may all be made to communicate by pipes or cocks as near the bottom as the deposit of yest will permit, so that drawing off the liquor from one will empty them all. But it is to be kept in mind that this method may be carried to an extreme: the quantity fermented may be too small; and the total quantity may be insufficient to keep up such a temperature as will ensure a proper degree of attenuation. Such a quantity of wort as will keep up the temperature *must* be used, or else artificial heat must be applied.

The suggestions here offered are not merely founded on conjecture. I can speak from actual and extensive experience, that the fermentation of small quantities produces not merely as good, but a far better beer, or all in

point of briskness, soundness, and body, that is obtained by the usual methods. I need not, indeed, appeal to my own experience: the superiority of home-brewed ales (when skilfully managed) is well known; and although this may be attributed by some partly to the finer portion only of the malt being extracted during the mashing, yet it must be admitted, even by these persons, that the fermentation on the small scale is at least as good as on the large. And if to this admission we add the evidence in favour of the small scale founded on theoretical considerations, a case is made out well worthy of the serious attention of the practical brewer.

Beside these advantages there is one other:—when very large fermentations are put in process, especially during summer, the quantity of yest employed is very small, for a great quantity would risk the souring of the drink. Now the smallness of the quantity of the yest used occasions a great waste of the bitter principle of the hop. For yest is much more bitter than the fermented worts which produced it, for reasons already explained. This vast quantity of valuable bitter principle is lost, because the brewer uses so little of his yest. And were he to adopt a process that would consume more yest, he might use less hops, and thus save some of his loss. As to the reputed ill flavour of the bitter principle of the hops contained in yest, part is attributable to prejudice, and part to a cause which a little experience would remove. And further, such bitter might be consumed in the making of inferior kinds of drink. The bitter of yest becomes much less disagreeable if the top brown scum be removed.

In a former part of this work it has been observed, that injurious consequences result from the practice of drawing great *lengths* from the malt so as to exhaust it perfectly, and afterwards expelling the redundant water by long continued boiling at a temperature somewhat above 212°. At this elevated temperature, the saccharine matter of the malt, which is so readily decomposable, is absolutely scorched, so also is the small remaining

quantity of unaltered starch. The volatile aromatic oil of the hop is also dissipated; and probably internal changes in the constitution of the dissolved matter are induced by the long continued boiling. An empyreumatic taste is often perceptible.

A very slight change in the process of the brewer would, in all likelihood, greatly improve the flavour and value of his drink. Let the first mashing be conducted with a smaller quantity of water than usual, so as to draw off shorter lengths of wort. Such wort will require no evaporation; and there will be, therefore, no risk of its acquiring any burnt taste. Let this wort be heated in the copper to a degree never exceeding 180°, along with the proper quantity of hops, until a perfect impregnation be obtained; then let the wort be drawn off and reserved. The wort of a second mashing, boiled down until sufficiently concentrated, may then be heated on the same hops to 200°, maintained at that temperature for some time, and then drawn off. A concentrated third wort may lastly be boiled, during a few minutes, on the now nearly exhausted hops; and thus will be extracted all that was valuable in that bitter. The different worts may then be mixed; and we are certain that they have not lost a particle of one of their ingredients, not even of their aromatic volatile oil. We need not apprehend any risk of a burnt flavour; for it is the wort of the first mashing, loaded as it is with dissolved matter, that is in danger of burning. The second and third are of so watery a nature, that there is little chance of their scorching.

Having, in the foregoing twelve sections, treated of the various particulars which must be attended to in order to produce malt drinks of the best quality, we proceed to consider a process closely allied to that of the brewer, to which all the preceding observations are introductory, and many of them equally applicable.

CHAP. VII.

DISTILLATION.

SECTION I.

PECULIARITIES OF THE DISTILLER'S FERMENTATION.

THE object of the distiller being essentially different from that of the brewer, it might naturally be inferred that there are differences in the processes adopted by each; and this is accordingly the case. In the general principle which directs the operations of both, there is a strict correspondence; but in the application of it there are peculiarities, without attention to which the result must be a total failure.

The theory of fermentation already laid down, as fully as the nature of this work required, is equally applicable to both brewing and distilling. Leaving it, therefore, to stand as the basis of both, it will be only necessary to advert to the practice; and as the practice of fermentation, so far as the brewery is concerned, has been sufficiently described, all that now remains to be done is to point out the particulars in which the brewery fermentation differs from that of the distillery, and then proceed to the operations which are peculiar to the latter.

The first point of difference is the material made use of:—the brewer uses malt only; but the distiller may properly use a mixture of malt and raw corn; or he may employ raw corn only. M. Clement obtained as much alcohol from raw as from malted grain. The reasons for using malt only in the brewery are the following:—Malt worts run from the mash-tun perfectly transparent, whereas from raw grain, or a mixture of it, the runnings are foul, and even in this state run off with great difficulty; for the matter of malt is much more soluble in water than the matter of corn. Malt worts are much less liable to acidity than corn worts, and acidity is more detrimental to the brewer than the

distiller. The process of malting adds greatly to the expense, but adds nothing to the quantity of alcohol producible; many are of opinion that it diminishes it. It is said, that unmalted barley affords excellent beer, but inferior ale.* The chief obstruction to the use of an admixture of raw corn in brewing is that the excise laws forbid it. The grist of the distiller consists of variable proportions of malt, barley, and oats, according to the price of grain.

The next point of difference between the two processes relates to the state of the grist. It has been already mentioned that the matter of raw corn is less soluble in water than that of malt. On this account it is necessary to compensate the less ready solubility by increasing the facility of penetrating the grain with the water. Hence raw corn requires to be ground much finer than malt. The greater fineness of the meal, and the less solubility of its farinaceous part, occasion a greater risk of setting the goods when the mash-water is added. Hence arises another particular to be attended to in mashing for distillation, namely, that the rake-machinery must be kept in brisker motion, and for a greater length of time. The admixture of chaff with the grist lessens the tendency to set.

Malt after being ground is always *mellowed* by exposure to the air, during which moisture is absorbed, and the weight is increased. Raw grain gains nothing by exposure to air; on the contrary, some of its own natural moisture evaporates from it, and it becomes a little lighter. The malt intended for distillation need not be of so good a quality as that which is to be used for brewing, indeed the worst kind will answer.

Beside continuing the mashing and racking process longer when the worts are intended for distillation, the temperature must be different. As raw corn becomes pasty with water of a lower heat than malt, or, in other words, sets more readily, we must not use a mash-water of so high a temperature as would be permissible in the

* Sup Enc. Brit. art BREWING

brewery,—about 145° or 150° will be safe for the first mashing. During the mashing, the gluten of the grain and of the yest act upon the starch; and they are assisted by the agency of water and a sufficient temperature; the consequence of which will be, as formerly explained, the formation of sugar by the change effected in the nature of the starch. So much starch being now removed by its conversion into sugar, the grain has undergone in the mash-tun the very same change as if it had been malted. In the next mashing we may therefore use water of a higher temperature without fear of setting; for there is now nothing or but little matter capable of setting; the second mash-liquor may therefore be as high as 180°. On the same account the third mashing may be performed with water at 200°. The third infusion is almost always sufficient to exhaust the grain; but a fourth may be made provided it is used merely as the mash-water of a subsequent and distinct brewing. Were it added to the other worts it would weaken them too much and diminish the product of alcohol. The concentration of the worts is a most important consideration: if there be too much or too little water present, the consequence is equally fatal to obtaining the full quantity of spirit, when the liquor is distilled.

There is a statement of M. Dubrunfaut which, although founded on experiments made with *must* or grape-juice, seems equally illustrative of the case of worts drawn from grain. He says to render evident the influence of water in the vinous fermentation let us take three fermenting tuns placed near each other, and of the same size. Into each pour 400 litres of the same grape must. Then to the second add four hectolitres of water, and to the third eight, taking care that the water added is of the same temperature in both cases, and also of the same temperature as the must. We then have three tuns differing only in the quantity of water contained in them. The fermentation first commences in that tun containing the greatest quantity of

water; next in that which contains less; and, lastly, in that to which none had been added: there will be in each case about one or two hours' difference. The pure must will have done working in ten or twelve days; that which has been somewhat diluted in three or four days; and that which has been most diluted in thirty or thirty-six hours. They will be found not to differ less in the quantity of alcohol produced when submitted to distillation: the pure must will afford 100 litres of alcohol, the diluted ninety-five, and the most diluted ninety, the strength of the alcohol being the same in each case.* Thus the more water was present the sooner the fermentation commenced, the sooner it ended, and the less was the quantity of alcohol produced.

In the report made to the board of excise by Drs. Thomson, Hope, and Coventry, the following statement is made: —"On most occasions three mashings were found sufficient to extract all the valuable matter of the grain; but sometimes four were found necessary. It is of consequence to use an ample quantity of water. It answers two purposes: — it most thoroughly extracts all the soluble matter from the grain, and it forms worts of a moderate degree of strength, which is very favourable to the process of fermentation. In general, the quantity of wort drawn in our experiments from each bushel amounted to twenty-two or twenty-three gallons; it was never less than twenty, a larger quantity than what distillers draw. In the course of our experiments we had occasion to remark that a greater length than now indicated did not prove beneficial." This was when the grist was composed of two parts of raw grain with one of the same grain malted; but when the grist was composed entirely of malt, the lengths per bushel were from twenty-three to twenty-five gallons. "But the quantity of worts, from a given bulk of grain, ought to vary with the quality of the grain, and should be regulated by their specific gravity. Daily experience has led distillers to believe that great strength of worts is

* Dubrunfaut, Traité de l'Art de la Dist. i. 254.

unfavourable to fermentation; while from a very fair instance of comparative trial, we conclude that a greater degree of dilution than that employed in our experiments is by no means necessary or serviceable. In our trials, the worts, at an average, had a specific gravity of nearly 1053." *

The temperature at which the wort is set to ferment is much the same in the process of the distiller as of the brewer. In summer it is cooled as low as the temperature of the air will permit; for at that degree the fermentation will be sufficiently energetic to rise its own heat so as to effect adequate attenuation. In winter the degree may be about 70° or 75°: the elevation of temperature resulting from the fermentation will be so continually reduced by the coldness of the air that any lower heat than 70° would not permit a sufficiently active inoculation with the yest.

In the fermentation lies one of the chief differences between the operations of the distillery and brewery. The object of the brewer is not so much the development of alcohol as of carbonic acid, and the destruction of the mawkish sweetness of the saccharine matter. Provided he obtains a full flavour on the palate, with a brisk acerbity, he cares little for the quantity of alcohol. It is even his object not to run the fermentation so low as to develop the total quantity of alcohol producible from the wort; for this would leave no saccharine matter unattenuated in the liquor to sustain the slow fermentation which always continues for a length of time after the apparent completion of the process. The object of the distiller is quite the reverse. He disregards flavour and permanence: every particle of saccharine matter left unattenuated is so much lost; the alcohol is the only valuable product, and therefore his whole attention is directed to urge the fermentation to the utmost pitch that can be done without incurring counterbalancing loss by acidity.

The distiller's fermentation is not of the slow gradual

* pp. 61. 63.

kind which it is the object in the brewery to induce: instead of the gradual accumulation of the *rock-work* head, he urges it to a tumultuous effervescence, often threatening the overflow of the tun. This energetic fermentation would be fatal in the brewer's tun where the generation of acidity is so much dreaded; but the distiller knows, that although acidity consumes and wastes a quantity of the materials capable of forming alcohol, this loss is not without its use, unless it be considerable. Against it he has to set down the more perfect attenuation which he has obtained, and the production of a greater quantity of alcohol than could have been developed had not the fermentation been urged so far as to occasion a slight acidity. Slight, indeed, it is in the hands of an experienced distiller; and the loss thus incurred is amply compensated by the more abundant returns of alcohol: without caution it will readily run to an extreme. Preventing the access of air towards the end of the fermentation much lessens the quantity of acid formed.

The fermentation is urged by the use of a larger portion of yest than the brewer employs; by the addition of successive quantities at proper intervals, so as to keep up a constant but manageable action; and by avoiding the cleansing process of the brewer in which not only is the yest removed, but the temperature is lowered by division of the wort into small quantities, and the fermentation is checked.

In consequence of these efforts attenuation to a great extent is effected: the heavy saccharine matter is resolved into the light liquor called *alcohol;* and the diminution of weight aided by the production of a liquid so light causes the specific gravity to fall almost as low as water, and sometimes lower. The resulting alcoholic liquor is technically called *wash.* In order that the wash shall be of the best quality so as to afford a spirit of the best flavour and greatest quantity, the fermentation should have been conducted slowly and steadily, ever until the liquor has become almost transparent.

To effect a complete attenuation in this manner is a work of difficulty, and requires no ordinary portion of skill: hence attenuation is often attempted to be ensured by violent fermentations which defeat their own end by the copious formation of acetic acid; and this, rising during the distillation along with the spirit, communicates to it a flavour by no means desirable. Indeed sometimes the most consummate skill and the most attentive care will not ensure a successful fermentation. Frequently we find a brewing to prove a complete failure, which had been conducted in the same manner apparently in every respect, and with the same materials in quantity and quality, as one that succeeded perfectly: so capricious and unaccountable are the results.

Whatever advantages are to be derived in quantity and quality of spirit by slow fermentations, they may be countervailed by the length of time employed in the process. The occupation of apparatus, time, and capital. may be such as to render the increased value of the product of a slow fermentation too dear a purchase. We must, therefore, take the middle course between the extremes. The fermentation must not be so tardy as to abridge the necessary quantity of business to be done in the distillery; nor must it be urged so tumultuously as to annihilate the profitable results of despatch by an alteration in the nature of the products.

Section II.

PROCESSES OF THE DISTILLERY IN DETAIL.

It is now necessary to describe a process in detail, such as the distiller is in the habit of performing.

The grist, as already observed, may consist of raw barley, oats, and malt, in proportions varying according to the price of grain and some other considerations. The malt may constitute so small a part as one tenth; but an eighth or a seventh will be preferable. If the oats predominate, they impart a peculiar flavour not agreeable to all palates: it is only perceptible to persons practised in

the different tastes of spirits. The oats may with great propriety be to the barley as one to three, or even may constitute one half the quantity of the barley.

The practice of some distillers is to mash four times with such quantities of water as will permit them to let down the first two worts into the fermenting tun, and ferment them together. The other two worts are so poor in saccharine matter that they are reserved to constitute the mash liquor for the next brewing; or else they are boiled down to a proper degree of concentration, and then fermented. Other distillers regulate the quantities of water for four mashings in such a way that the first wort only is fermented, and the other three worts are reserved for a future brewing. Those who act in the latter way employ more water for the first mashing than those who prefer the former. When the first mashing only is to be fermented, the quantity of water is so adjusted, that the wort, when drawn off, will indicate a specific gravity of about 1·050. In order to attain this gravity of wort, the quantity of water employed for the first mash should be twice the volume or bulk of the grist. For every quarter of grits employed ($= 17745\frac{1}{2}$ cubic inches, qu. pr.) the quantity of water should be 128 imperial gallons; or, more precisely, every ton weight of grist requires eighty-four imperial gallons of water. Difference of quality in the grain will afford differences of result.

As to the heat of the mash liquor, it has been already observed that where raw corn is used the temperature of the water added must be considerably lower than if malt only were concerned, as there is much greater risk of setting. The water may be let on such a mixed grist as that above described at a temperature of 145°, and higher in proportion as the ratio of raw corn diminishes. Were there no raw corn present the heat might be as high as 175°. As the conversion of starch of raw corn into sugar is not so easily effected as the mere extraction of sugar would have been if the corn had been malted, we must take care to allow a much

longer time for the mash, and to use much more agitation. The mashing machinery should be kept in motion for two or three hours; and the mixture must then be permitted to rest for another hour, so as to clear itself. The wort is drawn off partly through the false bottom of the tun, and partly from above the surface of the grains where the liquor has been cleared by subsidence. A variable quantity of the wort will be retained by the grains, which would occasion considerable loss but for the other mashings to which the grains are subjected, not indeed with the view of *dissolving* any thing more away from them, but to *wash* away that which has been already dissolved. Accordingly a second mash-liquor is let on; and as there is now no fear of setting, the starch having been all changed and removed, the heat of the second water may be as high as 180° or 200°. Its quantity may be equal to what was drawn off in the last mashing. The time of working the machinery may be about a quarter of an hour, and the period of rest about half an hour. When this second wort is drawn off, it measures more than the water used for producing it; for the grains are now less absorbent, and they have parted with some of the first wort which they had retained. The third and fourth mashes may be conducted in all respects like the second; and after this, the grains are as much exhausted as they can be, and are only fit to be used as food for cattle. The second wort will be found in specific gravity about 1·015, the third about 1·008, and the fourth about 1·003, or little greater than water; in other words, they will contain respectively pretty nearly fifteen, eight, three pounds of solid matter (now dissolved) in the barrel.

When the wort is let into the fermenting tun, its temperature should in summer be as low as it can be reduced; but in winter it may be at 70° or 75°. The yest is then added. As to the quantity of the latter, it is influenced by circumstances, but chiefly by its quality. Were the yest of the best quality, which seldom can be procured, one and a half part per cent.

by measure will suffice; more frequently four per cent. will be required, and often even a greater proportion. If the yest be good, the fermentation will commence in eight or ten hours; but sometimes it will not appear for many hours later. In summer the fermentation of a wort the specific gravity of which is 1·050, will be generally completed in three days, and in four or five if the weather is not at its maximum heat; but sometimes twelve days are required. The thermometer continues to rise for some days, but the progress of attenuation is not marked throughout by increase of temperature. Towards the latter periods of the fermentation the thermometer remains stationary, and even falls a little, while the attenuation is proceeding. The following may be considered a fair statement of the temperatures and specific gravities of a five days' fermentation: —

First morning,	therm.	70°	s. g. of wort	1·050.
—— evening,	—	70°	——	1·050.
Second morning,	—	72°	——	1·046.
—— evening,	—	76°	——	1·032.
Third morning,	—	80°	——	1·022.
—— evening,	—	84°	——	1·012.
Fourth morning,	—	88°	——	1·007.
—— evening,	—	88°	——	1·005.
Fifth morning,	—	88°	——	1·003.
—— evening,	—	86°	——	1·001.

This may be considered a good attenuation: the specific gravity is certainly sometimes reduced as low as water, and even perhaps to 0·999, but this very seldom occurs.

An attenuation so low as is here indicated can scarcely be attained, if the original specific gravity had been above 1·050; for if greater, the quantity of alcohol evolved will be too great to permit the fermentation to proceed to a sufficient length. Alcohol is an enemy to the vinous fermentation; and if added to a saccharine solution actively fermenting the process will be checked. I have sometimes examined wash in which the ferment-

ation had totally ceased, and which, on being evaporated, afforded a large proportion of saccharine matter, but of a highly disagreeable taste and smell. Such is a positive loss to the distiller, and it is sure to ensue unless the wort be in a proper state of dilution. Indeed, in all cases some saccharine matter escapes decomposition; but the distiller submits to the loss rather than run the risk of urging the fermentation too far, for in this way a much greater loss would be incurred by the formation of vinegar. When once the head of yest falls in the tun, neither further additions of yest nor increase of temperature will succeed in resuscitating the fermentation.

In the attenuation of the wash there are two causes acting against each other, and both affecting the specific gravity. By the remains of the undecomposed heavy saccharine matter the specific gravity of the wash is increased, and by the intermixture of the alcohol developed it is lessened. Dr. Thomson observes that the saccharometer does not give true information as to the degree of attenuation of wash without the following precaution:—Evaporate away all the alcohol from a portion of wash, and then make up in water what it had lost in alcohol: the saccharometer now indicates the true specific gravity.

As soon as the attenuation has proceeded to its utmost, the specific gravity of the wash would after a little time begin to rise again, owing to the formation of acetic acid, but this is prevented by submitting it to distillation. Suppose the whole charge of wash let into the still amounts to 8000 gallons, the distillation may proceed as rapidly as can run without coming foul or muddy, until 2400 gallons have been drawn off: these constitute what are called *singlings*. This spirituous liquor is exceedingly weak, in the average number of trials marking about 63° below proof on Dicas's hydrometer. The singlings are then *doubled*, that is, re-distilled; and spirit is drawn off until it begin to acquire an ill smell and taste. Even after this, the distillation

is urged; but the product is kept separate on account of its bad quality: it is called *faints*, and owes its peculiarity to holding an essential oil dissolved.

This is the common mode of proceeding; but I believe it is a better way first to distil singlings from the wash as long as the product is alcoholic; then to distil faints from the singlings; and, lastly, the finished spirit from the faints. In these three distillations, the lower the heat the purer the spirit which comes over, and the more certainly the fetid essential oil is left behind in the waters.

We must also take care in the application of heat that it is not applied to the still, as may be said, in too concentrated a form: there is always starchy matter lying on the bottom which a brisk heat will certainly scorch, and cause the communication of an empyreumatic flavour to the spirit. The better to prevent this from happening, there is generally appended to the interior of the still a piece of machinery which continually stirs up the sediment and prevents its sticking to the bottom.

There is another piece of machinery contained in the head of the still, the use of which is to prevent boiling over, the wash being subject to that accident. This machinery breaks down the bubbles as fast as they form, and so prevents an accumulation. The same object is sometimes effected by throwing a piece of soap into the wash; for being decomposed by the acetic acid present, its fatty part now melted spreads over the surface and breaks the bubbles. The quantity of soap used in this way has been sometimes considerable: I was once applied to by a distiller to contrive a method of recovering the soap from the spent wash, his profits being, as he declared, materially lessened by the consumption of this article. The soap does not injure the spirit further than sometimes giving a slight flavour to it. But now that the distiller is not urged by the excise laws to hurry his process through all its stages the use of soap is much less frequent than formerly.

It is hard to assign any quantity as the product of

spirit from a given quantity of malt, it varies so much with the quality of the malt and the skill of the distiller. In Ireland the average product assigned to a barrel of malt (= 12 stone) is about 8½ gallons (late Irish; or imperial, 6 gallons 5 pints 1⅗ ngs.) of spirit, twenty-four per cent. above proof by Dicas. The same quantity may be procured from a mixture of equal parts of raw corn and good malt; and the same quantity may be procured from sixty-eight avoirdupois pounds of good Jamaica sugar. Sugar spirit is exceedingly bad when new, but is, perhaps, the best of all spirits when kept in wood to a sufficient age.

After the singlings have been drawn off, the liquor which remains in the still is called still-bottoms: if obtained from grain it is excellent food for pigs.

Section III.

VARIOUS CONSTRUCTIONS OF STILLS.

Having now described the processes of the distillery, from the mashing of the wort to the distillation of the wash, it becomes necessary to devote a separate section to the consideration of that most important of all the distiller's apparatus, the still, the importance of which is evinced by the great variety of constructions which from time to time have been offered to the trade.

It is probably a general law, although in the present state of knowledge there are many exceptions, that all matter at a certain degree of heat changes its form, solids becoming liquids, and liquids assuming the form of vapours or airs. The degree of heat at which the change takes place is different in different bodies. This difference affords a means of separating bodies from each other, which in any other way it would be difficult or impossible to accomplish. Nothing more is necessary than to heat a liquid or a solid, composed of ingredients differing in volatility, that is, in capability of assuming the vaporous form: the more volatile ingredient will

separate in vapour, while that which is less so will remain unaltered.

A vapour is nothing more than a solid or liquid combined with heat. If water, for instance, be exposed to heat, the water and heat combine; vapour of water is formed, and this bubbles off from the water in the form of *steam*. If from this steam or watery vapour we contrive means of abstracting heat, the water no longer preserves its state as vapour, but resumes its original form of liquid. This is easily understood by reference to a kettle containing water boiling on the fire. The water at the bottom of the kettle, or next the source of heat, combines with heat, forms vapour, and this vapour is discharged from the spout in steam. If we abstract heat from this steam, as by holding a plate of cold metal or glass over it, the plate instantly becomes wet all over with minute particles of water *condensed*, as it is said to be when thus regenerated, on its surface. If in place of holding the plate over the steam we affix to the spout of the kettle a long tube of glass or metal, and thus compel the steam to traverse the tube, a condensation is more perfectly effected, and drops of water will run from the other end of the tube. But the tube, by abstracting heat from the steam, becomes hot itself: as soon as it is as hot as the steam it can abstract no more heat, and then the condensation ceases. Hence arises the necessity of keeping the tube cool, and this is easily done by causing it to traverse a large quantity of cold water. In this way the whole water contained in the kettle may be boiled away; it will be reproduced in the tube, and may be collected from it without the loss of a drop. This process is not only the principle but very nearly the practice of *distillation*, as it is called, and the simple apparatus described is nearly the model of a *still*.

A more commodious and effective form has indeed been given to it. The common still consists of three essential parts. The first is the body of the still or boiler; it is intended to contain the liquor to be dis-

tilled: it is generally made of tin or copper. The mouth of the boiler has a lid, in the centre of which rises a wide pipe; and this, after ascending perpendicularly, bends in a somewhat acute angle, and enters a deep tub filled with cold water, which it traverses in a spiral or worm-like manner, and at length issues out through the tub near its bottom. This spiral tube is called the *worm*; and the part of it which springs from the boiler sometimes swells out into a wide globular vessel immediately above the boiler: this is called the *head*, and seems to be of no great use. The action of this still is as follows:—The liquid to be distilled being introduced into the boiler, the head is inserted into the mouth of the boiler. The *beak* of the head, as the pipe is called and which terminates it, is then fitted into the worm, the two junctures are secured by *luting*, or cementing round with a paste composed of linseed meal and water. The fire is then kindled under the boiler; the enclosed liquor boils; is converted into vapour; is forced through the head into the worm, where being cooled by the external water, it falls into its original state of a liquid, and having run through the whole extent of the worm, is discharged at its open end. If the liquid be a mixed one, consisting of two ingredients differing much in volatility, the more volatile one distils over, while the more fixed one remains in the boiler, and thus an analysis is effected, which, however, is very imperfect, unless the difference of volatility be great.

Let us, for example, suppose that the liquid to be distilled is a mixture of strong alcohol and water, between the boiling points of which there is not a great deal of difference, that of the former being 176° and of the latter 212°. When the mixed liquid begins to boil alcohol comes over, but it is much weaker than it was before; for it has brought over some water dissolved in its vapour, in consequence of the affinity existing between the two liquids. The alcohol, continuing to come over, grows weaker and weaker, until at length nothing runs over but water. When the distillation com-

menced, there being a certain ratio of alcohol and water, the boiling point of the mixture in the boiler was neither 176° nor 212°, but some degree intermediate between both, say it was 190°. The boiling was thus low on account of the presence of the volatile alcohol; but in proportion as this distilled over, the cause of the great volatility being removed, it might naturally be expected that the boiling point became more and more elevated. This accordingly is the case; for it will be found that a thermometer kept continually immersed in the boiling liquid will slowly rise from 190° to 212°, and at this period the whole alcohol will have distilled over. The inverse of the boiling process is also taking place in the worm, for there the hot vapour is cooling, and it imparts its heat to the water which surrounds the worm; and as the motion of the vapour is from the top of the worm downwards, it is obvious that the surface of the water in the worm-tub is hottest, that it grows cooler towards the middle, and is perfectly cold towards the bottom. We now come to apply these simple positions to an important purpose.

It appears, then, that the whole extent of the worm presents differences of temperature, from that of the boiling liquor down to the natural coldness of the air. It appears, also, that the vapour distilling over consists of alcohol and water, fluids which differ in volatility. If they differ in volatility, they must also in condensibility; that is, if they become vapours at different temperatures, these vapours must be reconverted into liquids at different temperatures. Now there are all temperatures in the worm, from the maximum to the minimum of the degrees concerned. It is, therefore, obvious that as the mixed vapour traverses the worm, the watery portion will condense in the nearest portion of the worm that is a little colder than itself; while the alcoholic portion, not being condensible at that degree, will pass on to a sufficiently cool part, and there it also will condense. The separation of the two liquids does not take place suddenly at any particular part of the worm,—it is modified

by the affinity of the two liquids for each other. After the separation of the two liquids in the worm, they run on condensed and mixed together, and drop in a state of mixture into the receiver. The distilled liquor is therefore a mixture of alcohol and water, and there lies the grand defect in the construction of the still: for its worm first separates the alcohol from the water, which was the object to be accomplished; and then it defeats the object by mixing them.

To remedy this defect, a second distillation in the same apparatus is resorted to; for this volatilises a stronger alcohol, and a portion of the water is left behind in the boiler. A third and fourth distillation also become necessary for the same purpose; but after this, further distillations do not separate any more water: for then the affinity of the water and alcohol becomes so strong as to countervail their difference of volatility, and both distil over together. In order to effect the separation of any more water the affinities must be disturbed and modified.

It is obvious that there is a vast disadvantage to be thus encountered in the common still, when, in order to obtain tolerably strong spirit (yet even then far from being the strongest), we are compelled to consume time, fuel, labour, and apparatus in four distillations. The nature of the defect has been long known, and various ingenious efforts have been made to remove it, but until the last thirty years with little success. The object of improvers seems to have been fourfold:— 1st, shortening the time in which a given quantity of spirit of the usual strength can be obtained: 2dly, shortening the time, and obtaining a stronger spirit: 3dly, advantageously employing the heat which in the common process is wasted; and, 4thly, rendering the apparatus self-acting, and continual in its operation. The improvements seem to have commenced in Scotland, and the history of them is not a little interesting.

The Scotch distillers, previously to 1786, had sent large quantities of spirits to the London market, which

had occasioned a reduction of the price; and it was found that the revenue of the distillery had diminished. Frauds against the revenue were therefore suspected, and the London distillers obtained certain information that the duties were evaded in Scotland. This suggested the necessity of making separate laws for raising the duties in the different kingdoms. Therefore, in 1786, the license act for the Lowlands of Scotland commenced, and was to continue for two years. The principle on which this act was framed between the contending distillers of the two kingdoms was as follows:—The duty then paid by the English distiller was 6*d.* per gallon on the wash; and supposing that eighteen gallons of spirits, one to ten over proof, were taken from 100 gallons of wash, the duty amounted to 2*s.* 9⅓*d.* per gallon. The Lowland distillers were allowed to work stills of any capacity, on paying an annual license duty of 30*s.* per gallon on the content of their stills; and the spirits thus made were to be consumed in Scotland; but might be sent to England on paying 2*s.* per gallon additional duty, the strength being one to ten over proof. Thus it was computed, that the annual license duty of the Scotch distillers would be equivalent to the remaining 9⅓*d.* per gallon paid by the English distillers, on the grounds that the Scotch distillers could run off their stills only once in twenty-four hours. The English distillers hence expected to have the London market to themselves; but the Scotch distillers continued to send increased quantities, and the price of spirits fell very low in the London market.

In the beginning of 1788, the house of commons discovered that the Scotch distillers were in the practice of running off their stills five or six times in twenty-four hours. It was inferred that by misrepresentation they had obtained an undue advantage over the English distillers; and now, before two years of the license act had expired, an additional duty of 6*d.* per gallon was laid on Scotch spirits sent to England; the remaining 3⅓*d.* being reckoned an equivalent for the license duty. The

Scotch distillers now became bankrupt, and resigned the market to their rivals.

Such were the effects and origin of the license act. But the ingenuity of the distillers working under it had been constantly and successfully excited in virtually lessening the duties in proportion as they were actually increased. When the license act commenced, the distillers used large stills; and the duty being only *30s.* per gallon on the contents of the still, and the still being run off five or six times in the twenty-four hours, the duty paid was *2d.* or *3d.* per gallon on the spirits. In 1788, the duty was increased to *3l.*; and they arrived at running off their stills to twenty times in the twenty-four hours, by the simple expedient of reducing the size of their stills, and enlarging their furnaces. At this time the duty actually paid was not above 1*d.* per gallon; and hence they did not think any farther improvement necessary. In 1793, however, the annual license duty on the stills was increased to *9l.* and in 1797 to *54l.* per gallon; and now again the invention of the distillers was stimulated to accelerate the process. From repeated experiments they found, that the more shallow the still, the broader the bottom, and the larger the furnace and supply of fuel, the more rapid will be the distillation. By attention to these particulars, the Lowland distillers were enabled to run off their stills three times in an hour, or seventy-two times in the twenty-four hours. Mr. Millar at length constructed a still which seems to have approached very near to perfection. He gave *exit* to the steam at as many points in the shoulder of the still as possible: he added a fly, kept in continual motion in the head of the still, for breaking the froth, and preventing the still from running foul; he added also an agitator, which kept the boiling wash in continual motion, so as to prevent the deposition of any sediment; and the burning of any sediment that did happen to fall was prevented by the working of a piece of machinery, which constantly scraped it up from the bottom. This still, the charge of wash for which was sixteen gallons,

and of singlings was twenty-four, might be charged, run off, and discharged almost twenty-two times in an hour.*

It has already been shown that the chief defect of the still in use at this time, even in its most improved form, is, that although the worm by the difference of temperature, existing throughout its length, actually condenses the alcohol and water in different parts of it, yet it allows them to mix again, and they are discharged at the tail pipe together. It is obvious that if we can contrive means to collect the water, which condenses, separately in the upper part of the worm, and allow it to run off without intermixture with the alcohol which condenses lower down, the latter will be obtained much stronger. A simple method of effecting this purpose was contrived several years since by Mr. Coffey, an eminent and scientific distiller of Dublin. From the first and second rounds of the worm two pipes proceeded, which opened into the boiler of the still. The effect was, that as the most watery portions of the alcohol were condensed in these two hottest rounds of the worm they were conducted away by the two pipes which opened into them, and discharged into the boiler for re-distillation, while the stronger alcohol was condensed lower down and separately collected. Some of the early stills, as those of John Baptist Porta, Lefevre, and Glauber, were constructed on a similar principle, although differently carried into effect. In these the boiler was fitted with a head, and from this sprang a tube, either standing erect or twisted into a serpent, or bent into a zigzag. At the upper end of the tube was affixed another head, from the side of which proceeded a beak or lateral pipe for the discharge of the distilled liquor. In the upright tube the watery vapours would be condensed; nothing would pass through its whole extent but the alcoholic vapours; and these would be condensed in the upper head or capital, especially if this were surrounded by cold water, as was the case in one of the stills alluded

* Reports of the Committees of the House of Commons, 1798 and 1799.

to. Glauber's apparatus was a succession of separate close vessels, connected by tubes: when a mixed vapour consisting of alcohol and water was passed through these from a boiler, the most watery vapours would be condensed in the vessels nearest the boiler, and the alcoholic vapours would pass through these, because heated by the water too much to effect a condensation; and they would pass on to the vessels farther off and cooler, and there they would resume the liquid state. This simple apparatus was, in about a century and a half afterwards, the means of producing a revolution in the art of distillation, which exerted a powerful influence on the commercial interests of a nation.

A person named Edward Adam, an illiterate man, happening to attend a course of chemical lectures at Montpelier, while a Woulfe's apparatus was exhibited and explained, conceived the happy idea, that, beside its own proper uses, it might advantageously be applied to the purpose of distilling brandy from wine. Impressed with this idea, he did not rest until he constructed a small apparatus; and after numerous trials, he had the satisfaction to find that his expectations were fully answered. In 1801 he obtained a *brevet*. It will be easy to understand his still, from the following description, which is sufficiently accurate for the purpose: —

Suppose a copper vessel, shaped like an egg, standing or supported on its small end, and its upper or large end being perforated by two holes. Several such eggs as these are to be ranged in one straight line. They are all to be connected by copper bent tubes in the following manner: — A tube proceeds from the top of the first egg, and plunges down to the bottom of the second. From the second hole of the second egg proceeds another tube which plunges to the bottom of the third egg, and so on to the end. The tubes are to be soldered or cemented in their respective holes made in the eggs to admit them, and are to be open at both ends. From this construction, it is obvious that if the eggs are

half filled with liquid, and if one blows through the first egg, the air will bubble through them all, and pass out at the last.

The application of this apparatus is as follows:— Suppose that the series consists of but four eggs, and that wine is the liquid to be distilled, with a view of obtaining its alcohol; let the eggs be half filled with the wine, and let heat be applied to the first, so that it shall boil. It is obvious that the vapour of alcohol mixed with watery vapour will be discharged through the first tube into the second egg, where both vapours will be absorbed. The wine in the second egg is thus rendered more rich in alcohol than it was originally, and it is at the same time heated by the condensed vapours. But the second egg cannot become as much heated as the first; for the wine in the second is more alcoholic than that in the first, and therefore it will boil at a lower temperature. If it boils at a lower temperature, the result must be, that alcoholic vapours containing less water will be discharged, while water will remain behind. These alcoholic vapours will be absorbed by the wine in the third egg, which of course will then become more alcoholic than any of the preceding, and will boil at a still lower temperature than in any former egg. The alcoholic vapour discharged from the third egg, and now very strong, may be passed through a worm, and condensed in the usual manner. If we wish a weaker spirit we may dispense with the third egg; if we wish it stronger, a fourth may be added: for in every egg a new analysis of the alcohol takes place, and its watery part is deposited.

In the improved form of this apparatus, the worm was contained in a refrigeratory tub as usual, but the latter was not filled with cold water for condensing the vapours in the worm, but with cold wine. In progress of the distillation this wine became hot, and this heat was converted to an economical purpose; for when the alcohol had been entirely separated from the wine in the eggs, the watery rseiduum was let off by cocks, and the

hot wine from the refrigeratory was let in by a tube of communication, so that less fuel would be consumed under the first egg to bring its contents to the boiling temperature. Meanwhile the refrigeratory was filled with cold wine.

But here is an evident interruption of the process: during the time that the hot wine is being transferred to the eggs, and their watery residua running off, the fire has been withdrawn, and the distillation has been discontinued. Apparatus which remedy this defect have been constructed by other persons, and the process has been rendered continual by what may be almost called a self-acting still. It will be here necessary to advert to that of Derosne only, as it is the one most in use, and comprises the greatest number of advantages.

A sufficient idea may be conceived of Derosne's apparatus from the following account, which comprises only its general principle: — A copper boiler is set in a block of masonry with a fire grate placed under it, the mouth of the boiler is not fitted with a capital or head of the common kind, but instead of this it is exactly fitted with a tall copper cylinder standing perpendicularly over the boiler. About half way up the height of this cylinder, and in its axis, a slender tube enters it, and discharges a continual but small stream of the wine or wash to be distilled. This wine does not fall down directly into the boiler beneath, as it would if there were no obstructions in the way to prevent it. There are obstructions; but M. Dubrunfaut, from whom this account is taken, does not explain of what kind. The deficiency is supplied by M. Péclet in the following manner: — "The tall copper cylinder, or as it is called, the *distillatory column*, contains a number of diaphragms through which the wine falls in different very small streams like rain, so as to present a great surface to the vapour which passes it in a different direction. In some of these stills the ascending vapours are forced, at each diaphragm, to pass through a thin stratum of liquid, and thus to experience a certain degree of pressure.

Both arrangements are equally good." * The wine, by a contrivance hereafter to be described, enters the cylinder through the tube almost boiling: it falls, as already mentioned, in little showers through the different pierced shelves; but at the same time a copious issue of watery vapour is continually ascending from the boiling copper boiler below. The watery vapour at the boiling heat comes in contact with the wine streams almost boiling; the latter, therefore, receive heat from the former, and by so doing there is an exchange of state; the watery vapour, having lost heat, falls back as water; and the wine, having acquired heat, boils, and its alcohol in vapour rises higher up in the cylinder, where, meeting with wine, it is absorbed, and a more alcoholic wine is produced. This more alcoholic wine is also more easily disposed to part with its alcohol in vapour, by the action of the heat continually carried up the cylinder. The alcohol in vapour accordingly does forsake the wine, ascends higher, meets more wine, is absorbed, and again liberated in greater quantity. At length the portions of wine high up in the cylinder become very alcoholic, and the vapours of alcohol meeting no more wine pass on to a worm, where they are condensed into very strong spirit. This worm is immersed in a refrigeratory tub filled with wine, which thus cools the alcoholic vapour and becomes heated itself. This is the heated wine which flows through the slender tube into the cylinder, and is there distilled by the process just described, and which is in principle the same as in the apparatus of Adam. As this worm is never perfectly cold, and therefore would never perfectly condense the whole alcoholic vapour, the latter is transmitted through a second worm, which effects the purpose completely. The second worm also is surrounded and cooled by wine. †

When the watery vapour which rose in the cylinder from the boiler, and fell back condensed into it, happens

* Traité de la Chaleur, par Péclet, ii. 250.
† Dubrunfaut, ii. 153, where the account is given in full.

to carry down any alcohol with it, the latter is again volatilised; so that the boiler never contains any thing but water, and this water is in fact the water of the wine; for originally the boiler had been filled with wine, and was converted into water (or at least a watery liquid) by parting with its alcohol. As fast as the boiler fills with water, thus derived from the distilled wine, it is emptied by a cock placed in the bottom of the boiler. Two boilers answer better than one; for if they be arranged with respect to each other by means of a tube proceeding from the head of one, and plunging to the bottom of the other, they discharge the functions of two of the eggs in Adam's still. There is a hydrostatic ball-cock which regulates the discharge of the wine from the grand reservoir, and affords a continual supply of cold wine; first to the two worms to cool them, and to become hot itself so as to avoid waste of heat; and afterwards to the cylinder where the distillation actually takes place. After having parted with its alcohol, its watery portion falls into the boilers, whence it is let off when totally deprived of every particle of alcohol, and a new supply of wine as constantly is afforded by the hydrostatic cock. Another feature of this apparatus is, that when the alcoholic vapours enter the first worm, they are condensed; but as the weakest or most watery alcohol condenses in the first rounds of the worm, it is so contrived that this watery portion runs back by little tubes into the cylinder, where it is re-distilled. The worm at all its rounds has cocks and tubes by which the portions condensed in any part may be let back to be re-distilled, or else they may be all shut, or some may be left open, so as to let the whole or any part go back into the cylinder: we can by means of these cocks, therefore, obtain the alcohol at any degree of concentration required, within certain limits.

It is obvious that this still does not literally afford strong alcohol from wine or wash at one distillation, as is commonly said of it; for it actually undergoes repeated distillations in the cylinder. One apparent pro-

cess only is apparently necessary, and one fire answers for all. In its operations it is continual. There is a saving of fire, superintendence, and time; there is a greater product of alcohol, and the alcohol has a purer flavour because there can be no empyreuma, as the fire is never directly applied to the wine. Indeed the want of empyreuma has been found an objection to the still: the consumers were so dissatisfied at the want of the accustomed burnt taste, that the required flavour was obliged to be communicated by various empyreumatic substances.

Economy of time and fuel have been attempted by various other means, and, to a certain extent, successfully. In the old construction of the still, the boiler was contrived to expose a large surface of liquid to the action of the fire, by having it made of a considerable diameter. The stratum of liquid was thus rendered extensive and shallow, and the vapour rose from a great surface. The bottom of the boiler was made concave towards the fire; so that the heated air was detained in the concavity while it imparted its heat to the bottom, and was thus prevented from passing so rapidly away to the flue. The flue was also carried round the boiler before it ascended into the funnel, in order that the heat might be all abstracted from the current and transmitted through the sides of the boiler, instead of going to waste. The vapour, as it rose from the surface of the boiling liquor, was at once turned into the worm for condensation, without allowing it to ascend in a high head, where a portion of it was prematurely condensed and returned into the boiler.

Heat, through the intervention of steam, has been also applied to the boiler of the still instead of the direct application of fire. The boiler was surrounded by an outer vessel close all round, and into this the steam was admitted. By this contrivance it was found that the consumption of fuel was reduced to one fifth.

The following table of the comparative quantities of heat producible by the combustion of various kinds of

fuel has been collected by M. Péclet*, and may be applied to the purposes of those who employ heat, either on the large or small scale, as an agent. The combustion, in each case, is supposed to be complete; and the quantity of combustible from which the heat is derived is, in each case, a kilogramme, or in avoirdupois weight very nearly 2 lb. 3 oz. 4¾ dr.

Wood quite dry	3500
Wood as it commonly occurs, containing 25 per cent. of water	2600
Charcoal	7300
Bituminous coal	6000
Coke affording 0·15 of ashes	6500
Good turf	3000
Turf coke affording 0·18 ashes	6400
Hydrogen (a mean)	22762
Carburetted hydrogen	6375
Bicarburetted hydrogen	6600
Oxide of carbon	1857
Olive oil (a mean)	10120
Sulphuric ether 0·728	8030
Alcohol	5261
Tallow (a mean)	7912
White wax (a mean)	9990
Naphtha 0·827	7338
Oil of turpentine	4500

SECTION IV.

DIFFERENT SOURCES FROM WHICH ALCOHOL IS OBTAINED.

It will now be necessary to give some account of the different sources from which various kinds of spirit are obtained in different parts of the world; for in almost all parts that powerful agent has become one of the necessaries of life, which once was confined to the treatment of disease in the shop of the apothecary.

* Traité de la Chaleur, i. 220.

Potato Spirit.

It has been long known that potatoes may be made to afford a considerable relative quantity of alcohol; and of late years the process has been extensively conducted. In France there are two methods practised: in the first, the starch of the potato is fermented without any previous preparation; in the second, the starch is converted into sugar by means of sulphuric acid in the manner already explained, p. 68. There are large manufactories of potato sugar, and of spirit obtained from it.

The advantages afforded by converting potatoes to this use are that they are cheap; that they afford a good spirit; that the residuum of the distillation is good food for cattle; that grain is economised, and that less yest is consumed.

To obtain spirit according to the first process, the potatoes are to be boiled in steam for an hour; they are then bruised between two cylinders of wood or sandstone. Ground malt is to be mixed in a keeve with warm water in quantity sufficient to give the consistence of thin pap. The potato paste is next to be added, and the whole well stirred with a proper quantity of water until the mixture be completed, and no lumps remain. The stirring is to be renewed at intervals until the mixture be cold. The natural yest of beer, or that made artificially from rye, is lastly to be added: less is to be used than would be required for corn, since potatoes ferment more easily. Experience has proved that the addition of red beet-root or carrots to the potatoes and malt afford spirit of a better flavour and greater quantity. When the fermentation has been pushed to its utmost, the whole matter, both liquor and sediment, is to be introduced into the still and distilled as in any other case, taking proper precautions to prevent burning.

The process recommended by M. Siemen is to heat potatoes in steam a little above 212°; then to mash them well, and to add hot water alkalised by a very small admixture of caustic potash. The water is to be in such

quantity as to form a thin paste: this being quickly cooled yest is added, and the process conducted in the usual manner. It is said that by this method the quantity of spirit from a given weight of potatoes is greatly increased.

From 50 hectolitres, 30 litres (= 137·64 imperial bushels) of potatoes, along with 8 hectolitres (= 22·12 imperial bushels) of ground malt, we obtain 9 hectolitres (= 1101·2 imperial gallons) of spirit. * Cadet states that 800 pounds of potatoes will afford 30 pounds of spirit, which at that time he calculated to cost the distiller 36 francs, and to sell for 48.

The process for procuring alcohol from potato sugar need not be particularly described. The sugar once obtained from potato starch, it is easy to conduct the fermentation. During the conversion of the starch into sugar, they frequently apply the test of alcoholic solution of iodine to ascertain when the conversion of starch is complete: if it is not, the iodine will occasion in the solution a blue colour. From 50 kilogrammes (= 110·31 pounds avoird.) of potato starch, converted into sugar by sulphuric acid, are obtained from 20 to 25 litres (= 4·4 to 5·5 imperial gallons) of alcohol, at 0·935. †

According to Vauquelin, who examined 47 kinds of potatoes, the quantity of starch in 100 parts of potatoes varies from 12 to 24 parts. The general result was from 17 to 19 parts of starch per cent. According to Weinrich, every hundred parts of potato starch require but one or two parts of sulphuric acid, if the heat applied be a few degrees above 212°. Two or three hours are then sufficient to give crystallisable sugar. He applies the heat in wooden vessels by means of steam. ‡

During the last runnings of the fermented starch of potato when under distillation an oil is obtained, which was examined by M. Pelletan, and which he supposed to

* Le Normand, L'Art du Dist. i. 382.
† Dubrunfaut, Traité complet, i. 222.
‡ Brande's Journal, 1829, p. 418.

resemble the oil procurable from corn spirit. The two oils are, however, materially different.*

The yest thrown up by potatoes during fermentation, even with one fifth of their weight of barley, possesses but little energy; it is, therefore, not used in potato fermentations.

Carrot Spirit.

Mr. Forster extracted this spirit in 1770. Twenty pounds of carrots well cleaned from earth are left to dry in a proper situation for three days. The fibrous roots and herb being cut off, the carrots are boiled for three hours in 95 gallons of spring water; they are then to be broken down between rollers, reduced to a pulp, and the juice pressed out. This juice is to be boiled for five hours with some hops, then strained into a keeve; and when the heat has fallen to 66°, a little better than two gallons and a half of yest are to be added. In a tolerably warm summer the mixture generally ferments during 48 hours, it then lets fall its dregs; the temperature will have fallen to 58°.

Twenty-one imperial gallons more of juice prepared in the same way, and as yet unfermented, are then to be added warm, so as to bring up the temperature of the whole to 56°. The fermentation is renewed, and continues twenty-four hours. The heat again falls to 58°, the dregs are again deposited, and the liquor is then tunned. This produces a third fermentation, which continues three days; and during this time the temperature should be maintained at 44° or 46°. The fermented liquor is then to be distilled.

The product is about ninety gallons of singlings; which on redistillation afford rather better than twenty-one imperial gallons of ardent spirit. To produce this quantity, 2000 pounds of carrots are required.

In the Edinburgh Transactions for 1790, we find a paper by Dr. Hunter and Mr. Hornby, in which they give the details of the whole process.

One ton and eight stone of carrots, which, after being exposed to the air a few days to dry, weighed 160

* An. de Chim. et de Phys. xxx. 221.

stone, and measured forty-two bushels, were washed, topped, and tailed, by which they lost in weight eleven stone, and in measure seven bushels; and being then cut, were boiled with the proportion of twenty-four gallons of water to one third of the above quantity of carrots, until the whole was reduced to a tender pulp, which was done in three hours' boiling. From this pulp the juice was easily extracted by means of a press, and 200 gallons of juice were produced from the whole. This juice was boiled again with one pound of hops for five hours, and then cooled to 66°; and six quarts of yest being added, it was set to ferment. The strong fermentation lasted forty-eight hours, during which time the heat abated to 58°; twelve gallons of unfermented juice, which had been reserved, were then heated, and added to the liquor, the heat of which was thus raised again to 66°, and the fermentation was renewed for twenty-four hours more, the air of the brew-house being all this time at 46° and 44°. The liquor was now turned, and continued to work three days from the bung; and, lastly, it was distilled; and the first distillation was rectified next day without any addition. The produce was twelve gallons of spirit. It resembled the best corn-spirit in flavour, and it was proof. The refuse of the carrots weighed forty-eight stone, which, added to the tops and tails, made provision for hogs, beside the wash from the still, which measured 114 gallons.

Twenty tons of carrots, which will make 200 gallons of proof spirit, may be bought for 16*l*. Eight quarters of malt, or rather materials for distillation, consisting of malt, wheat, and rye, may be bought for 16*l*., and will also yield 200 gallons of proof spirit. The refuse from the carrots will be 960 stone, which, at one penny per stone, will sell for four pounds. The refuse, or grains from the malt, &c. will be 64 bushels, each bushel about three stone, which, at one penny per stone, will sell for sixteen shillings. It was supposed that the manufacturing of the spirit from carrots may be at-

tended with more expense than the manufacturing of it from malt; but it was imagined that the greater value of the refuse may compensate for that expense, and that the saving of corn may be worthy of attention.

Rum.

The syrup or mother liquor which remains after the crystallisation of sugar is called *molasses* or *treacle.* This, when diluted with a sufficiency of water, runs spontaneously into fermentation, but sometimes yest is added. When this has arrived at its maximum, the liquor is to be distilled in the usual manner. The product generally requires to be redistilled, in order to produce convenient concentration of the spirit. The fermentation which occurs in this case is chiefly the vinous, but it is also partly the acetous: whence it happens that the wash obtained from the fermented liquor contains acetic acid, sometimes considerable in quantity as well as a large portion of alcohol. At the heat of distillation, the acid acts on the alcohol, and forms acetic ether, which distils over along with the spirit, and communicates to it a very disagreeable flavour and odour. These are corrected by various means in different parts of the world: the leaves of different aromatic plants are thrown into the still, so as to communicate a more agreeable taste and smell.*

In the colonies, the peculiar ill taste of newly distilled rum is destroyed by allowing it to remain for a length of time in the hogsheads which contained the molasses until it loses the sharpness which it possesses when first distilled. The impregnation of molasses, aided by time, occasions the change of flavour. †

In Britain the same practice obtains: new spirit is stored in wooden vessels until the raw flavour is ameliorated; and it is singular that in glass or earthen vessels it never improves.

The manufacturers of rum are particularly careful to exclude from the fermenting tuns every kind of vege-

* Le Normand, i. 387. † Dubrunfaut, i. 106.

table substance and foul matter which does not undergo the vinous fermentation, but tends to induce the putrefactive stage. Such substances not only retard the vinous fermentation but taint the spirit distilled.

In France the molasses, which remains after the making of beet-root sugar, is converted into rum by a process similar to that just now described. From one hundred measures of such molasses eighty measures of spirit are obtained, of nineteen degrees of Cartier's areometer, equal in specific gravity to 0·935.*

Geneva.

The following was communicated to Dr. Thomson as the process for obtaining Dutch Geneva by a person who went to Holland expressly to learn the art: — 112 pounds of barley malt and 228 pounds of rye meal are mashed with 460 gallons of water at 162°. After infusing a sufficient time, cold water is added until the gravity of the wort is reduced to 45 pounds per barrel. The whole is let into a fermenting back at 80°; half a gallon of yest is added; the temperature rises to 90°, and the fermentation is over in forty-eight hours. The wash is attenuated until the gravity be about twelve or fifteen pounds per barrel. Both the wash and grains are then put into the still; the low wines are distilled off; these are redistilled, and the product is rectified. A few juniper berries and some hops are used to communicate a peculiar flavour to the spirit.†

Arrack.

Rice is convertible into a malt by a process somewhat different in detail from that employed for malting barley. In principle it is the same, but the execution is more difficult and more tedious. From the malt so obtained worts are extracted, and these, when fermented, are distilled in the usual manner; the product is called arrack. There is also a spirit distilled from the fer-

* Dubrunfaut, i. 108. † Supplement to Encyc. Brit. art. Distillation.

mented juice obtained from the cocoa-nut tree or palm, which is known by the name of arrack, but which is, in fact, a very different liquor. In Hindostan they give the same name to a spirit distilled from the fermented juice of sugar-cane.

Brandy.

When wine is distilled, a spirit is obtained called brandy. Strong wines afford the greatest produce of brandy; but its flavour is inferior to that produced from weaker wines which have been more frequently distilled. The different degrees of flavour depend on the presence of an essential oil in greater or less quantity; and more or less of this will be contained in the brandy according as the distillation has been much urged or not. Little of the oil comes over with the first product of spirit; but when the liquor remaining in the still has become watery by having parted with its alcohol, then its temperature rises, and the oil, scarcely volatile at preceding temperatures, now comes over abundantly, and gives its disagreeable taste to the brandy. This foul and weak spirit is called *repasses* by the French: by the British distillers of wash it is called *faints*: it is always kept separate for purification by subsequent distillations. A burnt flavour on brandy is by some considered a blemish; by others it is deemed an indispensable quality; so much so that when the process is too perfect to communicate empyreuma, burnt substances are added for that purpose. Scorched sugar is often preferred as it not only produces this effect but imparts a high colour to the brandy, without which the best quality would often prove unsaleable. Pure brandy like any other pure spirit has no colour: that of commerce always has derived it either from these artificial additions, or from some matter dissolved away from the timber of the cask which contains it.

The grape-cake which remains after the wine has been pressed out is called by the French *les marcs de raisin*: it retains always a portion of wine, and on being fer-

mented with a quantity of water not so great as to permit putrefraction, a vinous liquor is obtained, which affords a weak milky spirit called *blanquette*, by distillation. This, when redistilled, furnishes brandy of an inferior quality. The grape-stones, and the resinous colouring matter of the fruit, communicate an austere and burning flavour, which renders this spirit highly disagreeable. There is also considerable empyreuma.

A very inferior kind of brandy, having the same disagreeable taste, is obtained by distilling the lees of wine diluted with a little water.

The distillation of wines is practised chiefly in France; but also in Italy, Spain, and Portugal. The vineyards which furnish the greatest quantity of brandy are those of Languedoc, Bordelais, Angoumois, Orleans, and a few others.

Kirsch-wasser.

In Germany and Switzerland an ardent spirit is drawn from cherries, which obtains this name, a German word signifying *cherry-water*. It is manufactured chiefly in the environs of the Black Forest; but is sold commonly in London. About July or August the cherries are beaten off the trees with poles, and are collected indiscriminately, without regard to their various degrees of ripeness. They are thrown into ozier baskets, pressed, and the juice is received into proper vessels. The residuum is then either pounded so as to break the kernels, or the kernels are extracted and returned unbroken into the juice: both processes are equally successful. This juice is then fermented, and the agreeable flavour and smell of the *prussic acid* are thus extracted from the kernels. The vinous liquor is then distilled from a copper alembic with so little attention to the wholesomeness of the spirit, as we are informed by Argand, that they merely wash the copper (covered with verdegris collected during the preceding year) with some water and a besom. Le Normand says that the taste of the distilled spirit is

sharp and caustic; and in point of wholesomeness he considers it a downright poison.

M. Dubrunfaut informs us that a spirit distilled from prunes, the kernels of which are known to be energetically deleterious, has been used in France to adulterate the kirsch-wasser. The poisonous qualities of this admixture have attracted the attention of the French government.

Grass Spirit.

The excellent spirit, procurable in great quantities from the various kinds of grass, is singularly overlooked, while considerably more valuable materials are sacrificed in abundance for the same end. In Kamtschatka the value of grass for this purpose is duly appreciated. It is a peculiar kind, which, when allowed to heat by lying in heaps, evolves sugar just as barley would, although by a very different process. It is then mashed with hot water, fermented, and distilled. A spirit is thus produced which is highly prized by the natives.

M. Hoffman made an infusion with boiling water of six pounds of fresh roots of *couch*, or dog's grass cut and bruised. This being fermented with two ounces of yest was submitted to distillation. A watery spirit was produced, which, on rectification, afforded four ounces of a spirit as strong as that commonly obtained from malt, and much more agreeable in flavour. He therefore recommended this weed, which may be had, if not for nothing, at least for the expense of digging it out of the ground, to the notice of distillers, as a decoction of it may serve for cooling their mash, thus greatly increasing the quantity of their spirit. Of a decoction of these roots, with a little yest and hops, he likewise made a tolerably palatable beer, which kept good for three months. Perhaps treacle, in the proportion of half a pound to a gallon, would be no useless addition. A composition of this kind might also serve for making vinegar, equal in goodness to the common malt-vinegar used in this country, and 100 per cent. cheaper. This

root, which is now only used for manure, for which purpose it is burned, contains a large quantity of saccharine matter. From three ounces of the expressed juice M. Hoffman obtained two drachms and thirty-three grains of fine crystallised oxalic acid. In some parts of Sweden, in a scarcity of corn, they make these roots into bread. *

Some years since the late right honourable George Knox and myself made a number of experiments on the interesting grass called *fiorin*. Amongst other subjects we directed our attention to its fermentation. The method adopted was to boil the grass in a large quantity of water; to strain it off, and to boil down the decoction until it was sufficiently evaporated. Yest being added, an active fermentation ensued, which continued twenty-four hours. This wash, on distillation, afforded singlings, which, when doubled, gave a spirit which was very good, except that it had very much the flavour of the spirit called in Ireland *potteen*. From every fourteen pounds of fiorin hay the quantity of spirit produced was one pint, or 27·2 cubic inches. The growth of this grass is most luxuriant and remunerative. The Rev. Mr. Craig, near Lisburn, planted a plot of it in March, and made it into hay the same year. It produced at the rate of six tons per acre.† An acre of fiorin would, therefore, furnish 120 gallons (old measure) of spirit.

Potteen Whisky.

This far-famed spirit was some time since much more extensively manufactered in Ireland than at present. It seems to be more than ever prized on account of its scarcity, and it bears a high price. Its peculiar flavour is supposed to be caused by the practice of drying the malt from which it is made by turf. But it does not appear to me that this is the case. Some time since, being on a journey amongst the mountains in the most northern parts of Ireland, I learned that there was a

* Wiegleb by Hopson, p. 480.
† Statistical Survey of Antrim, p. 111. Appendix.

potteen distillery then at work; and, having despatched an emissary well known to the distiller to procure me admission, I was permitted to inspect the process. This place was famous for producing good spirit.

The distillery was a very small thatched cabin, at one end of which was a large turf fire kindled on the ground, and confined by a semicircle of large stones. Resting on these stones, and over the fire, was a forty-gallon tin vessel, which answered both for heating the water and as the body of the still. Over the fire was an opening in the thatch, with a very low chimney; and through this was conveyed away the smoke, after traversing the whole of the apartment. The fumes of the burning turf were so acrimonious that my eyes were exceedingly smarted; on perceiving which, the distiller desired me to sit down as a certain remedy. I did so, and immediately the pain ceased; the fumes occupied the upper stratum only of the air, they consisting chiefly of pyroligneous acid in vapour.

The mash-tun was a cask hooped with wood, at the bottom of which, next the chimb, was a hole plugged with tow. This vessel had no false bottom: in place of it, the bottom was strewed with young heath; and over this, a stratum of oat husks. Here the mash of hot water and ground malt was occasionally mixed up for two hours; after which time the vent at bottom was opened, and the worts were allowed to filter through the stratum of oat-husks and heath. The mashing with hot water on the same grains was then repeated, and the worts were again withdrawn. The two worts being mixed in another cask, some yest was added, and the fermentation allowed to proceed until it fell spontaneously, which happened in about three days. It was now ready for distillation, and was transferred into the tin body, which was capable of distilling a charge of forty gallons. A piece of soap,* weighing about two ounces, was then thrown in to prevent its running foul; and the head, apparently a large tin pot with a tube in its side, was inverted into the rim of the body, and luted

with a paste made of oatmeal and water. The lateral tube was then luted into the worm, which was a copper tube of an inch and half bore, coiled in a barrel for a flake-stand. The tail of the worm where it emerged from the barrel was calked with tow. The wash speedily came to a boil, and then water was thrown on the fire; for at this period is the chief danger of boiling over. The spirit almost immediately came over: it was perfectly clear; and by its bead, this first running was inferred to be *proof*. Its flavour was really excellent; and it might well have passed for a spirit of three months old. As soon as the upper stratum of water in the flakestand became warm, a large pailful of cold water from an adjoining stream was dashed in with sufficient force, as he said, to make the hot water run over, it being lighter; and this cooling process was continually applied to. In this way, the singlings were drawn off in about two hours; and the singlings of four distillations made one charge of the still to produce the potteen.

The malt was prepared by enclosing the barley in a sack, and soaking the sack and its contents for some time in bog water, which is deemed the best; then withdrawing and draining it. The malt was then made to germinate in the usual manner. When it had grown sufficiently, it was conveyed in a sack to the kiln, along with some sacks of raw corn, for the purpose of concealment. The raw corn was spread out on the kiln; but during the night when the kiln owner had retired to rest, the raw corn was removed, the malt spread on, dried, and replaced by the raw grain before day. The owner of corn drying on a kiln sits up all night to watch it. In this way discovery was eluded, and the malting completed.

Beside the much valued flavour of potteen, it has derived a part of its character from its being distilled entirely from malt. Now, however, about one fourth of raw corn is generally added. From a bushel of this mixed grist the potteen maker obtains a gallon of spirit

of what is called three-to-one strength; that is, three glasses or measures of spirit mixed with one of water afford proof spirit. This is much below the produce that ought to be obtained.

The body of this still cost one pound; its head about four shillings; the worm cost twenty-five shillings; the mash-tun and flakestand might both be worth twelve shillings. The whole distillery was, therefore, worth about three pounds; and it is purposely constructed on this cheap plan, as it holds out no inducement to informers or excisemen. Sometimes they have been on an extensive scale.

I doubt very much that the flavour of potteen depends on the smoke of turf used under the kiln on which the malt is dried. This distiller told me, that his spirit has the same smell and taste on occasions when coal had been burned under the kiln. His malt had no peculiarity of smell or taste, although it often has. I think it probable that these peculiarities depend on the nature of the fermentation, the urging of the distillation so low as to procure, not only the whole spirit, but much of the essential oil. I have found that by making an alcohol perfectly destitute of foreign flavour, dissolving in it a small quantity of essential oil from distillers' faints, and diluting with a little water, a spirit resulted which had very much the flavour of potteen, although not precisely. It is possible, however, that the turf smoke with which these mountain distilleries abound may be absorbed by the spirit while running, but most especially by the worts while under fermentation. It is well known, that there is a period of the vinous fermentation at which odours are very apt to be absorbed and retained. The steeping in bog water may also contribute; for in the subsequent drying on the kiln the heat may be sufficient in some degree to char the bog extract remaining in the malt, thus giving origin to the smell of turf on the spirit.

Service-berry Spirit.

The highly ornamental tree, the *pyrus aucuparia*, or mountain ash, affords clusters of scarlet-red berries,

which have a remarkably acerb and bitterish taste. Yet they resemble the grape in containing sugar and natural yest in the due proportions to produce a perfect and spontaneous fermentation. Having expressed a quantity of their juice I left it to ferment; and when the wine was perfect, it was distilled, and an excellent brandy was obtained. The quantity of brandy afforded by the berries cannot now be certainly ascertained; but I am almost sure, that one gallon of the juice produced half a pint of spirit, which was moderately strong. It is very probable, that the service tree might become a very valuable one if all its properties were known. It is a beautiful tree: its timber is valuable; and its berries, beside being beautiful, are capable of affording an excellent brandy.

Spirit from the Apple of the Potato.

"From experiments made in France, at various places, it appears that the fruit or apples of the potato yield, by proper treatment, as much alcohol as an equal quantity of grapes. The apples are to be bruised and fermented with about one-eighteenth or one-twentieth part their weight of some ferment, and then to be distilled." * These experiments require to be confirmed. If the result be not exaggerated, the stupidity of the world in not using potato apples instead of grapes is unpardonable. The taste of the potato apple, when ripe, is a mawkish sweet; but it has not one tenth of the sweetness of the grape.

Apple Spirit.

In Devonshire it is a common practice to distil a spirit from the lees of cider: it is there called *necessity*, and nothing but necessity could warrant its use. I once obtained a portion of spirit by the distillation of a hogshead of sour cider; and, after three rectifications, the last of which was at a very low heat, the spirit was tolerably good. A little chalk was used in the second distillation.

* Brande's Journal, vi. 157.

Section V.

RECTIFICATION OF SPIRITS.

All spirits, no matter from what source derived, are, if pure, perfectly identical in their nature and composition. They are, then, in all respects the same as the liquid known to chemists by the name of *alcohol*. This is a colourless liquor, of a penetrating smell and taste, destitute of any other peculiarity of either. Spirits distilled from beer, wine, and malt, will all be alcohol, but without proper precautions will be very different in their sensible characters: the beer spirit will have the abominable *goût* of the yest, the wine spirit will have the peculiar flavour of the wine from which it was obtained, and the malt spirit will have the disagreeable qualities of the faints. By appropriate treatment they may all be divested of their peculiarities.

It is known that the peculiar smell and taste of the different kinds of spirits depend on the presence of an essential oil, different in each case. We have one kind of essential oil from potato spirit, another from malt spirit, a very different one from brandy, and different even according to the variety of brandy. Brandies are imitated by preparing a pure alcohol, free from any peculiarity; dissolving an essential oil, derived by distillation from the lees of the wine which affords the brandy to be imitated, in the alcohol, and then letting down its strength by water. The lees of wine, on distillation, afford the greatest quantity of oil. When spirit has been distilled from wine lees, the residuum in the still is found to be a liquid floating over a great quantity of oil.*

One of the objects of *rectifying* spirits is the removal of this essential oil. Its presence is in many cases injurious, as in the making of perfumed essences. For preparing these, an odoriferous oil is dissolved in strong spirit; and if the latter has any peculiar smell, it will sensibly impair the purity of the perfume. Another use

* Baumé, Elémens de Pharm. 456.

of rectification is to remove a quantity of water, which common spirit always contains, and which renders it too weak for several purposes. Common spirit sometimes contracts an empyreumatic taste, owing to its being distilled from a wash which was not transparent when it ran from the fermenting tun ; hence it burnt in the bottom of the still, the latter being, perhaps, not provided with agitators to prevent such an occurrence. A skilful rectification will remove this empyreuma, unless it be excessive: in such cases, charcoal is a powerful adjuvant. Sometimes keeping the spirit in a charred cask will be found sufficient.

When wash is distilled, a very weak foul spirit is obtained, which is called *singlings*. When singlings are *doubled*, that is, redistilled, the first spirit which comes over, called *first-shot*, is tolerably strong, and is accounted more pure. Indeed the first product of any distillation is more free from oil than what comes after. When as much spirit has run over as can be produced without any smell of *faints*, that is, without too much impregnation of the essential oil, the whole produce of spirit is *whisky ;* and when it is sent out of the distillery, its strength is twenty-five per cent. above proof on Dicas's hydrometer. If this be redistilled, or rectified as the process is now called, from every hundred gallons of whisky, there are obtained eighty, the strength of which will be forty-six over proof, one per cent. more or less, according as the distillation has been slow or rapid. This is about the strength of what is commonly sold as rectified spirit. If this be once more cautiously distilled, a spirit comes over, the specific gravity of which will be about 0·820, and this is the strongest that can be procured by mere distillation. Up to this period, each distillation has rendered the spirit more free from oil, but it still contains much. If spirit of greater concentration be required, we must detach the water from it by engaging its affinity ; and this can be done by mixing with the spirit some substance which attracts the water more powerfully than the alcohol does. Such a substance, amongst many others,

is pearl-ash. If warm pearl-ash be mixed with rectified spirit, and agitated for some time, the pearl-ash will be found to dissolve; its solution will remain in the bottom as a separate stratum, and above it will float the spirit, now much stronger: for the pearl-ash has attracted water from the spirit, and has been dissolved in it. But the spirit has dissolved a minute quantity of pure alkaline matter from the pearl-ash, and holds it obstinately in combination. If it be distilled, some of the alkali remains in the still; but some of it also comes over with the spirit, and imparts to it an urinous flavour. Such spirit as this is unfit, by the presence of the alkali, for some purposes, to which it would otherwise be well adapted on account of its strength. Varnish-makers use very strong spirit for dissolving resins; and although alkalised spirit acts well as a solvent of such, the varnish made from it curdles in drying, and never looks well. Various other substances have been used for attracting the water, but they have all been shown by M. Dubuc to be objectionable.

M. Dubuc distilled alcohol from carbonate of potash and of soda, and in both cases obtained a spirit, which rendered violets green. Alcohol distilled from pure potash, or muriate of lime, afforded a precipitate with nitrate of silver. Distilled from quicklime, it soon deposited carbonate of lime; and from gypsum it acquired the property of changing the tincture of violets to the colour of decayed leaves. Glauber's salt rose during distillation in very small quantity. Acetate of potash that had been calcined gave over a little potash with the spirit. Sulphuric acid added in small quantity to spirit not exceeding thirty-eight degrees of the areometer allowed the spirit to come over pure. Calcined alum communicated to alcohol distilled from it the property of reddening litmus. Calcined sea-salt also rose in distillation. Pure alumina and potter's clay, well washed and dried, were found to be capable of taking some water from alcohol, and without altering it in any other way, or communicating any thing to it. M. Dubuc therefore recommends this process for obtaining alcohol at a greater degree of

concentration than could be obtained by mere distillation. Charcoal afforded an alcohol scarcely changed in strength, or in any other quality, except in being more fragrant and better tasted than before.*

The purifying power of charcoal has been made the subject of experiment by various persons. Lowitz ascertained, that by distilling common malt spirit from charcoal its peculiar smell was removed. He also found that charcoal removes the ill smell of spirits, without distillation, by merely agitating them. He divided ten troy pounds of common spirit equally into ten different vessels, and added charcoal powder in the following proportions: —Half a drachm scarcely altered the smell; and the spirit did not clear for six months. One drachm did no more; the spirit cleared in four months. With two drachms the spirit cleared in two months. Four drachms occasioned a very perceptible diminution of the smell; and the spirit cleared in one month. One ounce entirely removed the bad smell; the spirit cleared in a fortnight. An ounce and a half cleared it in eight days; three ounces in five days; four ounces in twenty-four hours; and five ounces in two hours.†

The same results as to the removal of the smell and taste were obtained by Kels; but both he and Hahneman have observed that the spirit contracts a pungent or biting taste, either by agitation or distillation with charcoal.‡

Wood-ashes were formerly used in rectifying: they were supposed to neutralise the acid contained in the spirit, and to fix the essential oil.* They probably acted only by the alkali present in them.

From some experiments of M. Cadet de Vaux, it appears that the peculiar or ill flavour of spirits, obtained from the wines of various mellow and sweet fruits, may be removed by a second distillation with milk, which renders the different spirits almost identical with each other, and much improved in quality.§

* An. de Chim. 86.
† Crell's Journal, ii. 246.
‡ Crell's Journal, iii. 271.
§ Dublin Phil. Journal, i. 280.

Formerly a practice prevailed in France of evading the duty on brandies by entering them as perfumes, they being mixed with some odoriferous oil for that purpose. The mode adopted for the subsequent removal of the oil was to dilute the spirit, and filter it in a close vessel through lime slacked in the air. The oil was detained by the lime, provided it was present only in a small proportion. *

It has been asserted that a kind of rectification in the first instance, or destruction of the essential oil, may be effected in spirit drawn from grain or potatoes, by mixing a small quantity of chloride of lime, or, as it was formerly called, oxymuriate of lime or bleaching powder, with the wash previously to distillation. M. Zeize affirms that the taste of such spirit resembles that of brandy.

The British distillers have been in the habit of ameliorating the flavour of their spirit, by adding a little sulphuric acid to the wash, and a great outcry has been raised against them for so doing; but the experiments of M. Dubue have proved that the practice is harmless.

It is known, however, that the simple process of agitating spirit, which holds a large quantity of its offensive oil in solution with water, distilling the mixture at a low heat, and rectifying it, will afford the spirit greatly ameliorated in quality. This was the process of Kunkel: it is effectual, but troublesome. Kunkel was the first chemist who turned his attention to the oil in spirit.

When the object is merely to obtain strong alcohol, without reference to the flavour of the spirit, the end may be obtained by simple distillation of rectified spirit from warm pearl-ash, from muriate of lime, or lime, in the manner first pointed out by Raymond Lully; but Dr. Menici has shown that the spirit distilled from lime must be originally strong, as otherwise it will be partially decomposed. †

* Baumé, Elém. de Pharm. 437. † Giornale di Fisica, 1825, p. 48.

It has been stated, and generally believed, that if a bladder half full of alcohol (0·867) be exposed to the air for some time, the orifice being well closed, it will be found to have become much stronger, being now only 0·817; and that in damp weather the spirit absorbs again the water with which it had parted. The bladder, it is stated, is in fact a filter which allows the passage of water, but retains alcohol. I have never been able to obtain these results to the extent specified. I have made the experiment on alcohol of this strength, and also of various lower strengths, with small and large bladders, with thick ones and thin ones; but a diminution of strength was the invariable result, unless the spirit were very weak; and then whenever an increase of strength did happen, it was extremely trivial.

M. Pajot-Descharme has effected the rectification of spirit, in the cold, by exposing it in a flat-bottomed dish to the action of an extensive surface of dry chloride of calcium contained in a separate vessel, and both included in a large close vessel. By employing successive quantities of chloride of calcium the water may be abstracted from the spirit until the latter is brought to 42° (Baumé).*

The strongest alcohol known is 0·791, or 0·792 at 68°. I once endeavoured to obtain it stronger by the following process:—A solution of perfectly dry chloride of calcium in alcohol (·810) contained in a retort was exposed to a temperature of about 50°. To the retort was attached a receiver, the two necks being accurately fitted by grinding, and the receiver was immersed in a freezing mixture composed of snow and muriate of lime. The whole apparatus was then exhausted by the air-pump. As I write from memory, after a lapse of ten years, I can only recollect that the process was exceedingly slow; that after some alcohol was thus drawn off, it became necessary to increase the temperature of the retort; and that after drawing off about an ounce of alcohol its strength appeared not to have been greater

* An. de Chim. et de Ph. Juillet, 1825.

than ordinary means would have afforded it. Its specific gravity proved 0·795 at 60°; and as the balance employed was not of the best kind, I could not be certain but that it might be 0·796, which would be exactly the strength which Lowitz assigns to alcohol distilled from pearl-ash. It is probable that this is the strongest procurable alcohol.

There are various methods practised of giving peculiar flavours to spirit, and thus imitating the more expensive kinds. Thus, by distillation from colcothar, spirit acquires the smell and taste of French brandy. The admixture of a very small quantity of nitric ether is said to do the same. The different qualities of brandies are imitated by first depriving spirit of all flavour, and then dissolving in it some oil distilled from the lees of the particular wine from which the brandy required should have been distilled. Wieglcb ascertained that fluoric acid gives to spirit the precise smell of arrack. But these are sophistications, and it is not our province to give information on such a subject.

In the present and preceding chapters an account has been given of the methods of obtaining alcoholic liquors from the different kinds of grain by an indirect process, which calls into operation principles which did not previously exist as such. We have now to consider a class of alcoholic liquors which are obtained by fermentation without any intermediate process or without the intervention of any principles which did not exist as such in the original sources of these liquors. These sources are the different fruits, the most perfect of all which, and the most valuable as to its products, is the grape.

CHAP. VIII.

WINE-MAKING.

The grape is the most perfect of all fruits: its excellence is equally conspicuous, whether we consider its delicious flavour or the numerous uses to which it may be applied, in the form of wine, brandy, and vinegar. It depends on no external source for any of the materials necessary to the elaboration of these articles; its supplies are within itself, of the most perfect quality, and in just proportion. Vinification is rightly considered the model from which the brewing of all fermented liquors should be copied.

In entering on the subject of wine-making, it is necessary to consider the nature and composition of the grape, the only fruit from which true wine is procurable.

Section I.

NATURE AND CONSTITUTION OF THE GRAPE. — PROPERTIES AND VARIETIES OF MUST.

The vine grows in all the temperate regions of the world; but it comes to perfection in warm climates only, and not equally in these; for as we approach the equator the quality of the fruit deteriorates. The best grape is, therefore, producible in a genial climate, chiefly between the fortieth and fiftieth degrees of latitude. There is a great diversity of species, some succeeding better than others in certain countries; and there is no species which succeeds equally well in all climates, a grape being in one place excellent, while in another place the same kind may be a very bad fruit. "In cold countries," says Neumann, "the vine, if it grows at all, never ripens its fruit; and even in France and Italy I have observed that the grapes produced on the south sides of hills are notably sweeter

than those which grow on plain grounds. Among the Tokay wine hills there is but one which directly fronts the south, and the advantages of its situation are not a little remarkable. From the extraordinary sweetness of its grapes it is called the Sugar Hill. It affords the most delicious of all the Hungarian wines, and is appropriated to the use of the imperial family."

Even in so limited an area as that of France, we find that differences of climate very materially affect the quality of the grape, and the wine made from it. The southern provinces afford the best and most spirituous wines; the middle provinces afford worse; and the northern produce the worst of all. The warmer the climate the more sugar is developed during maturition.

The following are the chief causes which influence the excellence of grapes:—Their species, the climate, the soil, the aspect, the goodness of the season, and the culture. Unless these causes operate favourably, good wine cannot be obtained from the grape; and not even then, if the process for making the wine be not skilfully conducted. In cold climates, the grape never ripens so as to contain much sugar; in very hot climates, its flavour is not delicate. A soil not very rich is more conducive to purity of flavour than one that is highly manured: the latter kind produces quantity of juice, the former quality of taste. The beneficial effects of man's fostering care become evident by comparison of the wild with the cultivated grape. Throughout America, north and south, the grape grows wild in vast abundance, yet the wine made from it is very inferior to what is made in the same parallel of latitude in Europe, where the fruit is cultivated. The growth of the banks of the Ohio may be an exception. The French settlers there have made tolerably good wine from several species of wild grape. Whether this is the effect of greater skill in the manufacturer or of a better grape is uncertain. France, now so remarkable for the excellence of its grapes, in the time of Strabo possessed none, and it was supposed im-

possible to propagate them in that climate. Yet culture has not only produced them, but abundantly, a twenty-sixth part of the whole kingdom* being now occupied with their growth. The vine has been introduced into Britain in the same manner, although before the Roman conquest it was utterly unknown there. Many excellent qualities now grow well in Britain in the open air, the chief of which are the muscadines, sweetwaters, millers, &c.

The vine is a very long-lived tree. Mr. Millar says, that vineyards will hold good in some parts of Italy above 300 years; and that vines of 100 years are accounted young. Yet one-year-old shoots are those that bear the fruit. The tree, when old, is of a considerable size, and its produce often exceeds a ton of fruit in one year. The colours of grapes are various; but the green and the purple are the most common.

The wines in most general use in Britain are as follow: —France supplies us with Burgundy, Claret, and Hermitage, which are red wines; and with some white wines, as Champagne, Frontignac, &c.: there is also a white Burgundy wine. Spain sends us Sherry, Alicant, Malaga, and Malmsey, all white wines; and Tent, a red wine. Portugal affords us red and white Port; Lisbon also red and white, and Calcavella, a white wine. Madeira and Teneriffe, white wines, come from the two islands of the same names. Tokay is a white Hungarian wine: Lachryma Christi is a red Italian wine: Hock is a white German wine. The Cape of Good Hope affords red and white Constantia, wines much in request: they are the only good wines produced by that country. The Cape wines are almost always poor and bad; for being made often from wild grapes, their juice is deficient in sugar, and requires to be boiled to a proper degree of concentration.

The following are sweet wines: — Malmsey, Malaga, Frontignac, Alicant, Tent, Lachryma Christi: the dry wines are Port, Lisbon, Calcavella, Claret, Hermitage, Madeira, Cape Madeira, Teneriffe, Sherry, and Hock.

Champagne is of two kinds; one called river Champagne, is white and *brisk;* the latter is red and *still.* Brisk wines are those which effervesce or sparkle; and still wines are those which do not.

The grape consists of the following materials: — Vegetable fibre; a peculiar ferment or yest; sugar in large quantity; potash; lime; three acids, citric, malic, and tartaric; a small quantity of an essential oil, to which the aroma and peculiar flavour of wines is in a great degree attributable; much water; a little mucilage; and in some species a red colouring matter said to be of a resinous nature. The relative quantity of these ingredients is influenced materially by a number of circumstances already mentioned.

The kind of weather in which grapes are collected greatly affects the value of their juice. It is strongest when the grapes have been gathered in dry weather, and after the morning dew has been dissipated. It is said that adventitious moisture is capable of increasing the quantity of juice a twenty-fourth part. A singular circumstance has been stated with regard to the necessity of collecting the fruit at a warm season. If the air be cold at the time, the fermentation of the juice afforded by such grapes will be slow and languid, and the wine will be weak. The vintage at Montpelier during 1809 gave ample evidence of this fact. A dry summer is sure to evaporate much of the water from the fruit still on the vine, and, therefore, to add to the sweetness, by increasing the relative quantity of sugar. In dry seasons, the sugar will be abundant, the juice deficient: in wet seasons, the juice will be abundant, and the sugar deficient.

Although the grape contains all the requisites for fermentation, as a ferment, a fermentable matter, and water, all in such relative quantities as would ensure a perfect fermentation, it is curious that grapes do not undergo that change while they remain whole. For the active ingredients are contained in separate divisions of the fruit, the sugar being deposited in the cells, and the fer-

ment outside of them. Again, the red colouring matter is contained in the husk, so that a purple grape affords colourless juice. White Champagne, for instance, is made from a grape so deep in colour, as to appear actually black; and sherry is indiscriminately made from coloured and colourless grapes although a white wine. This colouring matter is said to be of a resinous nature; it is insoluble in watery liquids, but soluble in alcoholic. When the husk is allowed to remain in the must during its fermentation, until a sufficient quantity of alcohol has been formed to render the liquor capable of dissolving the resinous colouring matter, the wine produced will be red, although the original juice had been white, or rather colourless. If the husks are not digested in the fermenting liquor, the result will be a white wine. Red and white port are produced from the same grape, the former with and the latter without the husk. If the colouring matter be really resinous, there must be some peculiarity in the resin which prevents its being precipitated by water. Red wine mixed with water retains its transparency. The red colouring matter is of an astringent nature; it communicates the same quality to the wine, as well as a slight roughness. The husk is capable of communicating but a light red colour: when the red is deep, it is the effect of artificial colour imparted; and a deep red colour is never a desirable quality. M. Duportal, however, denies that the red colour of wines depends on the action of alcohol on the husk.

The sugar, the most valuable of all the constituents of grapes, is first to be considered. We must not be misled by the ordinary acceptation of the word *sugar*, so far as to suppose that whenever it is mentioned it must necessarily mean common sugar, whether hard or soft. There are many modifications of sugar, or, in other words, there are several sweet substances which, by chemists, are considered as species of sugar; or they pass under the equivocal name *saccharine matter*. The two obvious divisions are the hard and soft kinds. The

latter of these cannot be made to crystallise: it remains in the form of a syrup, and is found in various fruits, and especially in the uncrystallisable syrup called *molasses* or treacle, which remains after all the common sugar has been obtained from the juice of the sugar-cane.

Hard sugar is obtainable from various sources, and it differs in its properties, according to the subject from which it has been obtained. Common loaf sugar is an instance of this kind; so also, notwithstanding the name, is what is called soft sugar, for this consists of minute crystalline grains. East Indian soft sugar is much whiter and more pure than West Indian; yet the latter sweetens liquids more intensely, showing clearly that quantity of sweetness is not commensurate with quantity of sugar; or, in other words, that different kinds of sugar may possess different degrees of sweetness. Hard white sugar differs from soft brown sugar only in being freed from the brown syrup or molasses: alcohol will wash brown sugar white. Fig sugar is the crystalline granular substance found on figs: it may be separated by pouring hot alcohol on them, which dissolves the sugar; the alcoholic solution being subjected to spontaneous evaporation, crystals are thus formed. This sugar is different from crystals of common sugar, or candy-sugar as it is called, in the form of its crystals. Manna is a species of sugar; and there are many other kinds, as beet-root and maple sugar; the former of which is manufactured extensively in France, and the latter in the northern and middle states of America, where it is considered nearly equal to that of the sugar-cane. A sweet matter may even be extracted from gentian root, one of the bitterest, and from young nutgalls, one of the most astringent of all substances. Lastly, the sugar of the grape may be obtained in an insulated form; and it differs from common sugar in being much more easily crystallised, in having less sweetening power, and in undergoing the vinous fermentation without any other addition than water.

In short, the measure of sugar is not sweetness. Molasses will impress a more intense sweetness on the palate than the purest sugar; and it is known to every one that the coarser the sugar the better it sweetens. Yet hard white sugar will afford much more alcohol than soft sugar or molasses. Hence the quantity of alcohol procurable is the test of the quantity of real sugar in a specimen, and not the sweetness of its taste. From all this we derive an important practical remark, that these grapes which have the sweetest taste are not necessarily the best for affording wine: they may afford less alcohol than a less sweet grape, and, therefore, a less generous wine. It is said that an experienced taste will distinguish the really *valuable* grape from the merely sweet-tasted one.

The tartaric acid and potash, contained in grape juice or must, are of course combined, and they form what is called *tartar*. This tartar is most abundant in *verjuice*, that is, juice of unripe grapes; and its quantity is inversely as that of the sugar, throughout the whole period of maturition. It is absolutely essential to a good fermentation, perhaps because it holds the ferment in solution: if it be totally withdrawn, the must will not ferment; but fermentation commences when the tartar is restored. While the must remains as such, the tartar continues in solution. But when the solvent powers of the must are diminished by the evolution of alcohol in it during fermentation, the tartar becomes less soluble, and it is at length deposited in a crystalline mass. Tartrate of lime is also deposited along with the tartar, and adheres to it so obstinately, that even when the tartar is recrystallised, tartrate of lime is found in the cream of tartar. The presence of tartar in the must not only assists fermentation, but adds to the quantity of alcohol. But the malic acid is injurious; and when it exists in great quantity in the grape it is unfit for making good wine. Cider and perry, although agreeable beverages, are not considered to rank as wines, and this is mainly attributable to their containing such an abundance of

malic acid. Our domestic fruits all labour under the same defects of containing a great quantity of malic acid, and accordingly they all afford wines vastly inferior to those procured from the grape, in which the acid is chiefly tartaric. Lime is made use of to remove any inordinate quantity of malic acid which the grape may happen to contain.

The quantity of alcohol producible from must is proportionate to the quantity of sugar which the must contained. Grapes of a very saccharine nature will afford the most alcoholic, or, in other words, *generous* wine; provided that the whole sugar undergoes decomposition. But a part may escape decomposition through the operation of a variety of causes. The quantity of yest present may be insufficient to produce total decomposition. This sometimes happens with grapes; but it frequently happens with other fruits; and when it does, the wine will contain alcohol and unaltered sugar: their relative quantity being determined by the quantity of yest. The same effects will follow although the original quantity of yest had been sufficient, but was withdrawn by racking off prematurely, leaving the yest in the lees; or by throwing it down by premature fining. Or the whole sugar will not be decomposed, should the temperature be reduced very much towards the end of the process; for then the fermentation will cease. This will always happen when the quantity of must under fermentation is so small that it does not maintain its own heat, by the energy of the chemical action going on: such must be occasionally invigorated by the addition of warm must to that which is fermenting feebly; or what is much better, the process must be conducted in some apartment kept sufficiently well aired. The consequence, in any of these cases, will be that the resulting wine will be sweet and less alcoholic.

If there be a sufficiency of yest present to decompose the whole sugar, and the quantity of the sugar is considerable, compared with that of the water, there will be a continued formation of alcohol, until its quantity be-

comes superabundant. The fermentation of a liquid may be extinguished by adding much alcohol to it: hence the abundant formation of it, in a fermenting liquor, will have the same effect. The consequence in this, as in the last case, will be that unaltered sugar will remain, and the wine will be sweet.

Suppose the relative quantities of yest, sugar, and water to be such as will conduce to a perfect attenuation; then the fermentation will proceed until the whole sugar is converted into alcohol. When this happens, the yest will also be exhausted: there will be little fear that the acetous fermentation will set in; and the wine will be full-bodied, spirituous, and sound, provided that there had not been too much water present. This wine will not be sweet; or, as it is technically expressed, it will be a *dry* wine.

The last case is founded on the supposition that not only the yest is so proportioned to the sugar as to decompose the whole of it, but that the decomposition is suffered to proceed as far as it can. A new case arises out of the possibility of checking the fermentation before all the yest and sugar are exhausted, as may be done by a variety of means already described. If these means be employed, the energy of the fermentation will be greatly diminished; unaltered sugar and yest will remain in a state of little activity, yet continuing their mutual action in a slow and gradual manner. This slow fermentation will go on for a length of time, and if the extrication of the carbonic acid is prevented by confining the wine, as in bottles, that gas will be condensed and retained in the wine. But it will be ready to escape by effervescence whenever the pressure is removed, as by decanting the wine. These are the circumstances under which *sparkling* or effervescing wines are produced. But it is obvious that no wine can sparkle if its fermentation had been actually completed in the tun.

After what has been said, it is scarcely necessary to observe, that if the relative quantity of sugar contained in the must be considerable, and that it is all attenuated,

the wine will be spirituous and strong. If the sugar be scanty, so will the alcohol, and the wine will be poor and acescent.

When there is a deficiency of sugar in the grape, or, as in this instance it may otherwise be expressed, when there is a redundancy of water, there are several modes of remedying the defect. The first is to boil down the must so as to evaporate the superfluous quantity of water. But no part of it should be boiled down so low as to approach the consistence of an extract, as the yest would then be deprived of its property of exciting fermentation. The second mode is simply to add a due quantity of sugar derived from some other source; and the purest will be the best as least likely to impart any new or undesirable taste. But the best mode is to use an additional quantity of sugar actually derived from the grape. This is done by increasing the ratio of sugar to the water in a quantity of grapes, and then infusing them in the watery must which is intended to be improved. To effect this change in the grapes three processes are employed. The first is to spread out the grapes on straw, and to dry them a little in the sun. The next is to allow the grapes to wither or dry upon the vines; the watery part thus exhales, and the sugar is virtually increased in quantity. The last method is the most ingenious. The stem which holds the cluster is half cut through so as to intercept the supply of moisture on its passage to the fruit. The cluster is then allowed to remain hanging, in order that the water may transpire through the husk, and the fruit become half dry; the juice thus becomes greatly enriched. Cherries, by being allowed to dry or half wither on the trees, are rendered far more sweet than they otherwise would be. I have effected the drying of cherries in this way to such an extent that their taste almost precisely resembled that of raisins, the latter having very little superiority.

It is indispensably necessary to enrich the juice of some grapes by methods like these; otherwise they will rapidly run into a hasty feeble fermentation, which

would again pass quickly into the acetous stage. The result would be a poor, spiritless, acidulous wine. Those wines which have been strengthened by evaporating the must are called *vini cotti*, or boiled wines: they are not much prized. Sometimes, instead of enriching the must with foreign saccharine matter, a practice which seems injurious is adopted; brandy is added, to form which had been the object of the saccharine additions. Sometimes the wine is altogether made from grapes, the juice of which had been concentrated by being half dried on the vine: of this kind is Tokay.

In order to ensure the greatest possible quantity of sugar which grapes are capable of elaborating, they must be allowed to ripen perfectly before they are pulled.

After a batch of wine has been finished, and it is found to be too weak and watery, its concentration is sometimes effected by congelation. The method is founded on the fact that alcohol does not freeze in cold however intense; but that mixtures of water and alcohol will freeze with facility in proportion as the water is considerable in quantity. Watery poor wine can be rendered as strong as may be required by exposing it to cold. A part freezes, which is water, holding very little alcohol involved. What remains is now much stronger, and it may be rendered still more so by a second freezing process. Stahl exposed several sorts of wine to intense cold, and by freezing separated so much as two thirds of watery liquid. The residuary wines were of thickish consistence: they were strong, and kept for several years, with free access of air, and changes of temperature that would have spoiled any natural wine in a few weeks.

It is possible that must may have the contrary fault; it may be too saccharine, and may not contain the portion of water necessary to a free fermentation. If a solution of common sugar be too much concentrated, additions of yest, however considerable, will have very little effect in causing fermentation. The same will

happen in grape must, and the remedy is as easy as obvious. Without the addition of water in such cases, the resulting wine will be luscious and heavy. This fault in the grape is more likely to occur in dry summers, and when the fruit has been allowed to remain on the tree after the period of maturity.

As grape juice spontaneously enters into fermentation without the addition of yest derived from a foreign source, it is obvious that a yest exists naturally in it. The constitution of this yest was explained in a former division of this volume, in which the theory of fermentation was developed. Hence no artificial yest is ever added to wine made from grape juice, or even to those domestic wines made from our own fruits, although such an addition becomes necessary in the manufacture of some of our domestic wines made from mere saccharine matter without the employment of any fruit.

When the grape is crushed, and its juice expressed, the solution of its sugar is brought in contact with its yest, both of which until this period were kept separate. The mixture now therefore begins to ferment, provided that the temperature is sufficient to maintain the decomposition.

Deficiency of yest in must is obviated by husbanding the small quantity which it contains, and subjecting the whole volume of fluid frequently to its action. This may be effected by beating down the head of yest which rises to the surface, and frequently mixing it through the must. And when the fermentation goes on in casks, the object will be accomplished by not filling up the casks entirely to the bung-holes so as to throw out the yest, but leaving some vacant space for the yest to collect, and frequently shaking up the whole, or rolling the cask. Racking off the wine from the lees should be avoided until the fermentation is complete. It is also very necessary in such cases that the temperature should be kept up by artificial heat, if that of the weather, or the spontaneous heat, should not at the time be

sufficient. Little yest and low temperature will be sure to spoil the wine, if it is intended to be a dry wine.

A redundancy as well as a deficiency of natural yest is a fault, but not of so detrimental a kind; for it can be rendered less active by slight boiling. But by this treatment its activity is only suspended, not extinguished: after some time it will recover its efficacy. Too great a quantity of yest is the fault of grapes produced in a cold climate; and wine made from such is apt to run beyond the vinous fermentation, and to pass into the acetous. When this is threatened during vinification, some additional sugar may be added, derived from any of the supplies already described, in order that the yest may exhaust itself in forming alcohol rather than vinegar. Or if this mode be not advisable, some solution of isinglass may be added: for this affects the yest of wine as it does that of brewer's wort; it precipitates it, and thus prevents its doing further mischief.

However essential to the perfect fermentation of wines a proper quantity of tartar may be, an excess of it is injurious. In some kinds of grapes this excess is found, and wine made from such is acerb, sour, and rough. The remedy adopted in this case, as well as in the case of an excess of malic acid, is to add some alkaline substance, but not in such quantity as to neutralise the whole of the tartaric acid.

Thus by proper management the natural deficiencies of certain qualities of grapes can be remedied by the wine maker in a variety of ways; and from a very indifferent kind of grape a good wine may be produced.

It has been lately ascertained that charcoal has a singular power in absorbing and combining with the natural yest in must; so much so that must may be preserved for a length of time. The following statement has been made by M. Leuchs:—"Charcoal was added to the grape must in the proportion of 100 grains to a litre (2·1 pints); or, if very much inclined to ferment, rather more charcoal was used. When the liquid had settled and become clear and colourless, it was removed

from the charcoal, and put into bottles, or casks, to be closed up and preserved. It will not enter into fermentation, even in close vessels; for the charcoal has absorbed the ferment. Nevertheless, the ferment has not lost its powers by combination with the carbon; for if left in the must the latter begins to ferment, but only where in contact with the former.*

Section II.

FERMENTATION OF MUST. — MANAGEMENT OF THE WINE.

The best wine is always obtainable from juice taken from the bruised grapes with very little pressure. It will be still better if the grapes have been carefully picked from decayed and unripe ones, the astringent stalks being rejected. An inferior quality of wine will be afforded by unpicked clusters, and by strong pressure of even the best grapes, after other juice has been obtained from them by less pressure. Lord Bacon also says, " Where the wine-press is hard wrought, it yields a harsh wine that tastes of the grape-stone." Wine made without pressure is called in Italy *vino vergine.*

To obtain wine in its greatest perfection, the total quantity of the fermenting juice must be considerable. I have elsewhere said that in order to brew ale in perfection, its quantity ought not to be considerable. But in that case attenuation is not the object; a quantity of unfermented saccharine matter ought to remain. In the case of wine the reverse obtains; the sugar must be entirely attenuated if the wine is to be dry, and very nearly attenuated, even though it is to be sweet. Now if the quantity fermented be small it will be scarcely practicable to attenuate the whole sugar; but this will be easily done if the quantity be large, and the wine will then be generous. Artificial temperature will be the best substitute for a great volume; or, in other words, where the quantity cannot be otherwise than small, the temperature must be moderately elevated by art towards

* Brande's Journal, 1829. 418

the end of the fermentation. The degree of fermentation will be the best criterion for the degree of heat necessary.

It would be of no avail to give the minute details of the different processes employed in different countries for obtaining the various wines. It will be sufficient to give a general account, leaving the reader to apply the principles explained in the preceding pages.

The juice is obtained by persons in wooden shoes treading the grapes, either in baskets, or troughs, or tubs, with the bottoms perforated with numerous holes, through which the juice runs into a vat placed beneath. The stalks must be carefully picked from the fruit, as they impart an astringent taste, and impair the wine. The husks, after being sufficiently pressed, are reserved for making vinegar, or for the preparation of verdigris, or for pearl-ashes by combustion (*cendres gravelées*, Fr. *Cineres clavellati*, Lat.). Chaptal directs that the juice be all collected ready for the fermentation at once; successive quantities added occasion successive fermentations, and the result is a bad quality of the wine. This, however, is denied by Duportal. The must, almost as soon as obtained, begins to ferment actively, provided the temperature be 60°; for now the yest and sugar are brought in contact. The same phenomena, nearly, take place as has been already described in the case of brewers' wort. The temperature ought to be maintained, as nearly as possible, at 62°: for at a lower degree the fermentation is feeble; and at a higher, if the quantity be large, it is tumultuous. The fermentation is allowed to proceed for a longer time if the must was strong, or if the wine is intended to be dry, and a shorter time if the wine is to be of the sparkling kind. After the fermentation has proceeded as far as is intended, it is poured into casks, taking care not to draw off either the lees or the head of yest. The fermentation is here renewed; the casks are constantly kept full to throw off the yest, and to prevent the dissipation of aroma, alcohol, and flavour. After some time, the wine is put into other

casks, leaving the lees and head behind; and when it has been sufficiently depurated, the bungs are put in tight, and the wine is left to deposit its tartar, and to ameliorate. Four or five years at least will be required; but wines will often improve for twenty years, if in wood.

On this part of the subject. the observations of professor Duportal are so adequate, succinct, and important, that I shall extract the chief of them.

In these casks the wine undergoes a new elaboration, which renders it turbid, and reproduces a slight internal motion which is called the insensible or secondary fermentation. This intestine motion is to be encouraged or moderated, according as the wine drawn from the vat contains an excess of sugar or yest. If we do not wish to have a sweet wine, the insensible fermentation must be allowed to convert the sugar into alcohol, and thus to strengthen the wine. If there be too much yest without sugar, the fermentation must be immediately checked, either by removing the sediment and scum, and clarifying the liquor so as to extract all the yest which it contains; or by adding to the liquor some sugar for the fermentation to act upon, and thus give it a strength which otherwise it would not have had. The progress of fermentation expels much carbonic acid and scum from the bung-hole, which renders it necessary to add more wine so as to keep the vessel always full. The cask is then to be carefully bunged; and generally no further thought is given to the wine until it is fit for use. The liquor, when left at rest, very soon throws down all that is not completely dissolved in it, and even a portion of the tartar: whence results a sediment, known under the name of *lees*, which is usually separated from the wine: for this sediment acts on it in the nature of a ferment, especially when assisted by agitation, change of temperature, and other causes. In this case, as also when it is necessary to remove the fermentable substances, the wine undergoes certain manipulations, re-

duced by M. Chaptal to three, viz. racking, sulphuring, and fining.

Racking of Wines.

This is performed by drawing the wine into another cask, defecating it, and leaving behind the lees, consisting in general of ferment, altered by the fermentation of the must, some ferment unaltered by the operation of mucilage, tartar, and colouring matter. The lees, however, are not always the same from every kind of wine: the quantity of tartar varies, as also that of the colouring matter, according as the wine is more or less spirituous: in different wines there is more or less of the ferment, and this has undergone more alteration in some wines than in other. Thus a sweet Spanish wine does not contain any unchanged ferment, because the sugar in it is more than sufficient to decompose the whole of this substance: by adding more ferment to this wine you will diminish its sweetness, and increase the alcohol. On the contrary, a meagre wine of Burgundy will afford a great quantity of unaltered ferment, because the deficiency of sugar did not permit the whole of it to be decomposed. By the addition of sugar to this wine, the fermentation would be renewed, and more alcohol produced. The racking of wines is a necessary operation for the proper keeping of them. In general, this operation should be renewed whenever there is a considerable sediment at the bottom of the cask. Some wines, however, may be kept upon their lees, such as those of St. Thierry in Champagne: these will continue to improve, if kept upon their lees for four years, provided they are contained in casks of a very large size. If we consider the different nature of different wines, and of their lees, we shall easily perceive that racking is not equally necessary for all of them. If, for instance, it is a very weak wine, it cannot be racked off too soon; for the small quantity of alcohol contained in it will not be able to prevent the acetic fermentation taking place from the action of the ferment in the lees. But if it is a very

generous wine, early racking is not necessary, because the great proportion of alcohol renders the ferment of no effect. Moreover, a sweet and sirupy wine will become improved by keeping on the lees, because the sugar contained in it will be acted upon by the fermentable principle of the lees. Even a very tart wine, when kept upon its sediment, will grow better, when its tartness is owing to a too slow and incomplete fermentation, in which the sugar has not been entirely converted into alcohol. M. Chaptal, in the following passage, clearly establishes the truth of this assertion:—"We must only," says he, "draw off those wines which have been well made: if a wine be very tart, or very sweet, we must let it undergo a second fermentation upon its lees, and not draw it off until the middle of May; it may even stand until the end of June, if it continues tart. It sometimes becomes necessary to return wine upon its lees, and to mix them well together, that a new fermentation may be excited, which will ameliorate the wine." There are certain rules to be observed in the racking of wines: it should never be done in frosty seasons, nor when a moist wind blows; a dry cool wind is preferable: it is most advantageously done just previously to the periods of the shooting of the vine, its coming into blossom, and the turn of the grape; for it is at these periods the wine ferments most. In every wine country experience has demonstrated the proper time for this operation.

Sulphuring of Wines.

Whatever care is taken in the racking of wines, they will again ferment, unless they undergo the operation of sulphuring; that is to say, if they are not impregnated with sulphurous acid gas, by means of burning sulphur matches in the casks, either when completely empty, or containing a few pailfuls of wine only, to which more wine is added every time the burning is renewed. At Marseilles, in Languedoc, for the purpose of sulphuring wines, they employ must which has been

so strongly charged with sulphurous acid gas as never to have fermented; two or three bottles of which, mixed with each cask of wine, will also preserve that from fermentation. The sulphuring by burning matches has one disadvantage, that of depriving the must of the flavour of the fruit, and communicating to it an unpleasant taste. On this account, other antifermentable substances are sometimes employed. Thus M. Perpere recommends sulphuric acid; M. Astier employs the peroxide of mercury; and M. Parmentier has proposed the oxide of manganese, which is less hazardous.

Fining of Wines.

There still remain in these liquors certain heterogeneous substances which do not fall down by rest: the fining of them is generally performed by fish-glue (isinglass) previously softened into a viscid fluid by maceration in a little of the wine. We find that the wine becomes more limpid, and a sediment is formed, which renders a fresh racking necessary. Ox-blood and white of eggs, especially the latter, may also be used. Chaptal says that gum-arabic succeeds; and that wine rendered turbid by the lees may be cleared by coarse salt, calcined flints, starch, rice, milk, beech-chips, &c. all of which he supposes to induce a slight fermentation.

The last method of preserving and ameliorating wines consists in the art of mixing them, so as to render them less alterable, and to impart to them the most agreeable flavour. This art, although perfectly well known to the manager of the cellar, is not yet known to the chemist. A wine mixed with some other wine can acquire more strength, colour, aroma, and flavour, only by its principles undergoing some re-action, more or less sensible. If, for example, it be required to correct a very acid wine, owing to tartar, sugar may be added; for this substance, by increasing the proportion of alcohol, will precipitate the tartar. He will thus avoid the necessity of having recourse to the sirupy wines, which are not

to be found in all countries, and which always bear so high a price.

To the observations of M. Duportal on the means of preserving wines we may add the remarkable circumstance in their history, that if two kinds which keep perfectly sound by themselves happen to be mixed, there is a chance that they may be injured. Neuman says, that " if the spontaneous diminution of a cask of Hungarian is made up with Rhenish, though both keep extremely well by themselves, the mixture presently spoils." Yet mixtures of different qualities of wine are often made with a view of correcting some fault; but from the above observations it is plain that mixtures are not to be made indiscriminately. To mix them with good effect is a great part of the manufacturer's art; and his operations in this way are as frequently dictated by fancy as by real knowledge.

When wines are kept in wood, they always suffer a diminution of quantity, but an increase of value. The part that escapes is water; for the wood seems to act as a singular filter, allowing water to pass through, but refusing a passage to the spirit. Hence wines, by keeping in wood, become more spirituous, and at length, after a long lapse of time, too much so for drinking.

By keeping, another sort of improvement also takes place, — the alcohol seems to enter into more intimate combination with the other ingredients. Hence if they have been kept in glass, as through this there can be no transpiration of water, they afford less alcohol on distillation than when new. Old wines, therefore, are more mild; and as their alcohol is retained by a stronger affinity, they exert a less degree of action on the nervous system. They intoxicate less than new wines, which, holding their alcohol more loosely combined, permit it to exert its influence more speedily. This intimate combination produces another kind of amelioration. Almost all wines while quite new, and for a year or two, contain a considerable quantity of acidulous tartar, which communicates a harsh sourness. But

when the alcohol and the other constituent parts of the wine combine by time, the menstruum becomes a less perfect solvent to the tartar: it accordingly solidifies on the sides of the cask. This more abundantly takes place if the wine had been kept in wood, it having the property of permitting the transpiration of water through its pores; and even if kept in glass after this, a further deposition of tartar will take place. The wine is now mild, mellow, and strong-bodied, although less intoxicating; and it is in this state only that it becomes a desirable and wholesome beverage.

It has been lately found that the mellowness which age gives to wine may be attained in a very short time by a simple contrivance. Soemmering put four ounces of red Rhenish wine into a tumbler in winter: its mouth was tied over with moist bladder, and the tumbler placed in the shade. In eighty-one days the wine was reduced to one half, was in high preservation, had crystals of tartar floating on its surface, and others on its bottom: it was of a darker colour than before, but was brighter and finer than ordinary; its smell was stronger and more enticing; its taste, although stronger, more spirituous, and more aromatic, was yet milder, more grateful, and more mellow than ordinary. It was found to contain one half more alcohol than similar wine which had not been so treated in the tumbler. Thus the bladder had permitted the evaporation of water, but had prevented that of alcohol; hence the strength of the wine and the deposition of the acid salts. Soemmering, therefore, proposes that wine should be kept in bottles not corked, but tied over with soft bladder, in which state it will in twelve months become as mellow as in twelve years in the cask. The shallower the vessel, and the wider its mouth, the sooner will the effects be produced.

These facts have in substance been confirmed by M. St. Vincent. He states from long experience that by closing bottles of wine, by means of parchment or bladder instead of corks, we may attain in a few weeks the good effects of many years.

Wine intoxicates less effectually than the quantity of brandy which it would afford on distillation; and for this reason, that the brandy is held in chemical combination, and its qualities are modified by the other combined substances. That the alcohol is thus retained in chemical combination with other matter, by a somewhat energetic affinity, appears by the experiments of Fabroni, who found that if he added ever so small a quantity of brandy to wine, and then mixed with it a large portion of subcarbonate of potash, the brandy was thrown up to the surface, where it formed a floating stratum. But if he did not add brandy, the addition of potash occasioned no appearance of separation of the brandy natural to the wine, it being held combined with the other ingredients. Hence Fabbroni drew the erroneous conclusion that wine only contains the elements of brandy, and not the spirit itself ready formed. This has been since proved to be an error.

The effects of wine and its spirit on the animal economy are therefore different: those of alcohol are sudden, violent, and transitory; those of wine are gradual, gentle, and lasting.

Section III.

DOMESTIC WINES.

Having now explained, at sufficient length, the practice of fermentation in the case of ales and foreign wines, as well as the theory of the different processes, all that remains on the subject of wines is to lay down a few processes for obtaining some of the best, from the fruits of our own country. The theory and general practice are the same; but there are differences of manipulation to be attended to, arising from the peculiarities and poverty of our fruits, without attention to which even a tolerable wine will not be obtained. The chief defects of British fruits, so far as wine-making is concerned, are the deficiency of sugar and the redundancy of malic acid. The coldness of the climate is the cause of the former,

as appears plainly from the fact that grapes grown in this country are as deficient of sugar as any of our other fruits, unless an artificial climate be made to act on them, as by causing them to grow under glass. The coldness of the climate may even be the cause of the inordinate acidity of our fruits.

The natural ill qualities of our fruits must therefore be corrected by art; and to do this with effect, to imitate the qualities of the more perfect fruits of warm climates, constitutes the whole secret of domestic wine-making. Every economist, housekeeper, and servant, — every cookery-book and receipt-book is full of processes for making a multiplicity of domestic wines. These never take into account that an unvarying process cannot be adapted to the ever-changing nature of our fruits, the qualities of which are different, according as the season has been wet or dry, cold or warm; according as the soil was exhausted or well manured; according as the trees were skilfully or ignorantly pruned, and several other circumstances not necessary here to enumerate. These popular processes, therefore, almost never succeed: hence our domestic wines have a bad character; and hence the art of making them is but little cultivated. In almost no instance, so far as domestic economy is concerned, can the principles of chemistry be applied with better effect than to the preparation of our native wines. And in a national point of view it is to be lamented that no sufficient encouragement has been given to the art, either by the legislature or by the various learned societies which in other respects have so materially contributed to the progress of knowledge.

The object of the present section is to detail a few of the various processes which are so current for affording domestic wine, and which it is so much the advantage of owners of even small gardens to apply to practice. A garden may produce more fruit than the proprietor can consume as such, and it may not produce sufficient to render a sale worth while; what better can be done with the overplus than to convert it into wine? And it will

even happen almost always, that be the quantity of fruit ever so great, its conversion into wine will prove better economy than the sale of it. The processes which follow will be of little value unless the operator applies the principles already laid down; and, without so applying them, it will be quite in vain for any person by merely reading the processes to become competent to make even passable wine.

Wine from unripe Gooseberries.

The following process is taken from Dr. Macculloch, whose labours are well known and duly appreciated: —

The fruit must be selected before it has shown the least tendency to ripen, but about the time when it has nearly attained its full growth. The particular variety of gooseberry is perhaps indifferent, but it will be advisable to avoid the use of those which in their ripe state have the highest flavour. The *green Bath* is, perhaps, amongst the best. The smallest should be separated by a sieve properly adapted to this purpose; and any unsound or bruised fruit rejected, while the remains of the blossom and the fruit-stalk should be removed by friction or other means.

Forty pounds of such fruit are then to be introduced into a tub carefully cleaned, and of the capacity of fifteen or twenty gallons, in which it is to be bruised in successive quantities by a pressure sufficient to burst the berries without breaking the seeds, or materially compressing the skins. Four gallons of water are then to be poured into the vessel, and the contents are to be carefully stirred and squeezed in the hand until the whole of the juice and pulp are separated from the solid matters. The materials are then to remain at rest from six to twenty-four hours, when they are to be strained through a coarse bag, by as much force as can be conveniently applied to them. One gallon of fresh water may afterwards be passed through the *marc*, for the purpose of removing any soluble matter which may have remained behind. Thirty pounds of white sugar are

now to be dissolved in the juice thus procured, and the total bulk of the fluid made up with water to the amount of ten gallons and a half.

The liquor thus obtained is the artificial *must*, which is equivalent to the juice of the grape. It is now to be introduced into a tub of sufficient capacity, over which a blanket covered by a board is to be thrown, the vessel being placed in a temperature varying from 55° to 60° of the thermometer. Here it may remain for twenty-four hours or two days, according to the symptoms of fermentation which it may show; and from this tub it is to be drawn off into the cask in which it is to ferment. When in the cask, it must be filled nearly to the bung-hole, that the scum which arises may be thrown out. As the fermentation proceeds, and the bulk of the liquor in the cask diminishes, the superfluous portion of must, which was made for this express purpose, must be poured in, so as to keep the liquor still near the bung-hole. When the fermentation becomes a little more languid, as may be known by a diminution of the hissing noise, the bung is to be driven in, and a hole bored by its side, into which a wooden peg is to be fitted. After a few days this peg is to be loosened, that, if any material quantity of air has been generated, it may have vent. The same trial must be made after successive intervals; and when there appears no longer any danger of excessive expansion, the spile may be permanently tightened.

The wine thus made must remain during the winter in a cool cellar. as it is no longer necessary to provoke the fermenting process. If the operator is not inclined to bestow any further labour or expense on it, it may be examined in some clear and cold day towards the end of February or beginning of March, when, if fine, as it will sometimes be, it may be bottled without further precautions.

To ensure its fineness, however, it is a better practice to decant it towards the end of December into a fresh cask, so as to clear it from its first lees. At this time,

also, the operator will be able to determine whether it is not too sweet for his views. In this case, instead of decanting it, he will stir up the lees so as to renew the fermenting process, taking care also to increase the temperature at the same time. At whatever time the wine has been decanted, it is to be fined in the usual way with isinglass. Sometimes it is found expedient to decant it a second time into a fresh cask, and again to repeat the operation of fining. All these removals should be made in clear, dry, and, if possible, cold weather. In any case it must be bottled during the month of March.

The wine thus produced will generally be brisk, and similar in its qualities (flavour excepted) to the wines of Champagne, with the strength of the best Sillery.

Inattention, or circumstances which cannot always be controlled, will sometimes cause it to be sweet and still, and sometimes dry.

In the former case it may be remanufactured the following season, by adding to it that proportion of juice from fresh fruit which the operator's judgment may dictate, and renewing the fermentation and subsequent treatment as before. In the latter case, as its briskness can never be restored, it must be treated as a dry wine, by decanting into a sulphured cask, when it must be fined and bottled in the usual manner. Such dry wines are occasionally disagreeable to the taste in the first or second year, but are much improved by keeping.

If the whole marc be allowed to remain in the juice during the first fermentation, the process will be more rapid, the wine stronger and less sweet; but it will acquire more flavour. If the wine is intended to be very sweet as well as brisk, the quantity of sugar may be increased to forty-pounds: if less sweet and less strong, the sugar may be reduced to twenty-five pounds; it will then be brisk, but less durable, and ought to be consumed within a year. When the quantity of sugar is thirty pounds, it will be, perhaps, better to use fifty pounds of fruit than forty as generally recommended.*

* Macculloch on Wine-making, 3d edition. 235.

Wine may be made by nearly the same process from unripe currants, and unripe grapes.

In this process it may be observed that no brandy is added to the wine after it is finished, although it is the invariable practice amongst makers of domestic wine to add it. Dr. Macculloch says that this practice has been introduced under the mistaken notion of preventing wines from turning sour, and enabling them to keep a longer time. But he says that this admixture decomposes wine, and that although slow, the process is certain. The first and most conspicuous effect is the loss of that undefinable lively or brisk flavour, which all those who possess accuracy of taste can discover in French wines, or in natural wines. Brandy is not added to wines in France or Germany: the finer wines, claret, Burgundy, and hock, are totally destroyed by it. But the practice is universal in the wines of Spain, Portugal, and Sicily, which are intended for the English market. They are at first rough and strong; but kept long enough in the cask they at length ameliorate; their elements combine intimately, and their aroma is developed.

If, however, brandy, or, what is more general, common malt spirit is to be employed, the quantity of sugar is to be diminished at the rate of two pounds for every quart of spirit to be added.

Wine from Ripe Gooseberries.

This kind of wine may be made according to the same formula. Although the fruit should have been red, the wine will not be so: its tint will be a flesh colour; for the red colouring matter is precipitated during the process. The following will not afford quite so good a wine as the preceding; at least it will require a far longer time to ameliorate to the same degree of goodness.

Ten gallons of gooseberries are to be bruised in a tub, and left so for twenty-four hours. The pulp thus prepared is to be introduced, either at once, or in successive portions into a hair-cloth or canvass bag, and submitted

to pressure. The matter remaining in the bag is to be returned into the tub, and five gallons of tolerably hot water are to be poured on; the whole is to be well mixed up. After thus remaining in the tub well covered for about twelve hours, the matter is to be pressed through the bag, and the liquor obtained is to mixed with the original juice. The solid matter of the fruit is then worth very little, and may be thrown away.

In every five gallons of the liquor, consisting of the mixture of the original juice with the infusion, twelve pounds of white sugar are to be dissolved perfectly.

If the liquor be now left to itself, it will, after some hours, show symptoms of a commencing fermentation. In proportion as the fruit is ripe the temperature of the weather ought to be high. Should it be very cool weather, the liquor should be placed near the fire. If the gooseberries were unripe, or just ripening, the fermentation will take place at a lower temperature, and with more activity.

The progress of the fermentation should be frequently ascertained by tasting the liquid, it becoming continually less sweet until at length the sweetness totally disappears: at this period the fermentation is complete. When the fruit has been over-ripe, or when the weather is remarkably cool, the last portions of sugar remain a long time unaltered, and the fermentation is suspended. Placing the containing vessel near the fire will always renew the fermentation, so long as this degree of heat is kept up the fermentation will proceed. When the quantity of wine under fermentation is very considerable, it will generally keep up its own temperature.

Should the season be so warm, and the fermentation so rapid, as to excite fears of souring, which, however, can never happen while the quantity is so small as ten or twenty gallons in each fermenting tub, we can readily avert the danger by racking off from the lees, having first skimmed off the head of yest.

When the fermentation has totally ceased, the wine is to be racked off as clear as it can be procured. To every

five gallons of it two quarts of brandy, or good old malt spirit, are to be added, well mixed, and let to settle: for the spirit causes a separation of flocks which previously had been in solution. After subsidence for perhaps a month, the clear liquor is to be cautiously drawn off; introduced into a cask which it just fills; and set by in a cool cellar for a great length of time. It is seldom that the impatience and curiosity of inexperienced makers of domestic wines for family use can brook the delay of keeping the wine long enough to mellow sufficiently. The wine just described will require five years at least to be in its best condition, and must have been kept in wood all that time; it may then be bottled. A much shorter time will, however, render it tolerable.

Although from the general directions already given it would be easy for the reader to make wine from any required fruit, it will, perhaps, be more satisfactory to lay down the proportions and details relative to some other wines, nearly following Mr. Carnell as to proportions. *

Red Currant Wine.

Bruise eight gallons of red currants with one quart of raspberries. Press out the juice; and to the residuum after pressure (i. e. the *marc*) add eleven gallons of cold water. Add two pounds of beet root sliced as thin as possible, and let them infuse, with frequent mixture, for twelve hours; then press out the liquor as before, and add it to the juice. Next dissolve twenty pounds of raw sugar in the mixed liquor, and three ounces of red tartar in fine powder. In some hours the fermentation will commence, which is to be managed according to the details given for gooseberry wine. When it is perfectly over, add one gallon of brandy; let the wine stand for a week; then rack off, and let it stand for two months. It may now be finally racked off, bunged up in the cask, and set by in a cool cellar for as many years as may be required to ameliorate it.

* The quantity of wine intended to be produced in all cases is 18 gallons

White Currant Wine

May be made according to the same formula, from white currants nine gallons, white gooseberries one gallon, white sugar twenty-five pounds, white tartar an ounce, bitter almonds two ounces, water nine gallons, brandy one gallon. The beet root is of course to be omitted.

Black Currant Wine

Is to be formed according to the same formula, by using black currants six gallons, strawberries three gallons, raw sugar twenty-five pounds, red tartar four ounces, cold water ten gallons, brandy three quarts.

Strawberry or Raspberry Wine.

Bruise six gallons of either fruit; press out the juice; on the marc pour seven gallons of water; infuse for twelve hours, and press out the liquor. Add the latter to the juice, and mix with them six gallons of cider. Dissolve in the mixture sixteen pounds of raw sugar, and three ounces of powdered red tartar. It is now to be set to ferment; the rinds of two lemons and two oranges cut off thin, as well as their juice, may be thrown into the fermenting vessel, and when the process is over, the rinds may be removed. Three gallons of brandy are to be added at the proper time. For raspberry wine, a gallon of juice of red and white currants ought to be substituted for a gallon of the water above directed.

Elderberry Wine,

To be made according to the process for currant wine, from elderberries ten gallons, water ten gallons, sugar forty-five pounds, red tartar eight ounces, ginger root sliced four ounces, bitter almonds three ounces brandy one gallon. The ginger root and bitter almonds may be allowed to infuse in the liquor while it is fermenting; they are then to be removed.

Damson or Cherry Wine.

Eight gallons of the fruit, with about one eighth of the stones broken, water eleven gallons, sugar thirty pounds, red tartar six ounces, brandy one gallon. Press out the juice, and infuse the water for twenty-four hours on the marc, so as to obtain flavour from the stones. Then proceed as in other cases.

Mead or Metheglin (white).

The juice expressed from two gallons of white currants, boiling water fifteen and a half gallons, honey thirty pounds, tartar three ounces. These are to be well mixed by constant stirring for a quarter of an hour, and then allowed to ferment. When the fermentation is complete, and the liquor clear, one gallon of brandy is to be added, and it is to be immediately bottled. In a few months it will be fit for drinking, and will sparkle in the glass. Some, however, prefer having it as a still wine, and use it as a summer draught mixed with water.

Red Mead

May be made by using six quarts of red currants, and two of black, instead of the foregoing two gallons of white currants, along with a pound of beet root cut into the thinnest slices. Some persons make mead on the large scale, for sale, of mere honey and water, without fruit; but the article which is thus produced, is flavourless and heavy, and is by no means in general request.

Cider White Wine.

A mixture of apple juice sixteen gallons, honey sixteen pounds, white tartar four ounces, cinnamon broken, cloves, and mace, of each one ounce. Enclose the aromatics loosely in coarse canvass; and suspend them in the liquor while it ferments. The fermentation being over, add one gallon of rum.

Spruce Beer.

Although this beverage is known under the name of *beer*, it is in fact a wine as much as many others that are acknowledged as such. It is of two kinds, brown and white; the latter is by far preferable, and is made as follows: —

Take seven pounds of the cheapest loaf sugar; dissolve it in four gallons and a half of hot water. When the temperature has fallen to blood heat, mix in about four ounces of essence of spruce, and dissolve it perfectly by agitation. Then add half a pint of good solid yest from a brewery, and mix thoroughly. A fermentation will soon commence which, if it be summer, will rapidly go through its stages; but if in winter, must be maintained by keeping the cask in a warm apartment. When the fermentation very perceptibly subsides, the liquor is to be drawn off, the cask well washed, and the liquor returned. A second fermentation, inconsiderable in degree, will take place, and when this diminishes the liquor is fit for bottling. The bottles should be wired down, and laid on their sides until the liquor becomes brisk and in high order. This will be known by a trial of a bottle; and it then becomes prudent to set the bottles on their end lest they should burst. When kept too long in this posture the beer is apt to become flat; in which case the bottles must be placed on their sides again.

Brown spruce beer may be made exactly according to the same formula, except that in place of white sugar an equal weight of molasses or treacle is to be made use of.

Ginger Beer.

This also should be considered a kind of wine; it is made as follows: — Take two ounces and a half of the best ginger, reduced to a coarse powder. Pour on it four gallons of boiling water, and let them stand until cold. The liquor is then to be strained through a *tamie*

or flannel. In this are to be dissolved four pounds of loaf-sugar; and half a pint of solid yest is to be added, along with two ounces of cream of tartar. If the weather be not sufficiently warm, the cask containing this mixture is to be set near the fire, so as to excite a brisk fermentation. As soon as this subsides, the liquor is to be racked off clear, the cask washed out, the liquor returned, and allowed to work a day or two longer. It is then to be drawn off, without agitation, into strong bottles or earthen jars, which, when well corked, are to be wired down.

This beverage, if in good order, froths high in the glass when poured out, and retains its carbonic acid for a length of time. Ginger has this remarkable property of occasioning a high, close, creamy head upon all effervescing liquors. An extemporaneous and pleasant imitation of ginger beer is generally made by dissolving thirty grains of tartaric acid with a quarter of an ounce of white sugar in half a pint of water. With this solution are to be mixed six or ten grains of finely powdered ginger; and afterwards twenty-four grains of bicarbonate of soda in finest powder. The whole is instantly to be well mixed up, and drank while effervescing.

Wine from Vine-leaves.

Not only does the fruit of the vine afford wine, but even its leaves, young shoots, and tendrils, are capable of being converted to this use. Dr. Macculloch says, "chemical examination has proved that the young shoots, the tendrils, and the leaves of the vine, possess properties and contain substances exactly similar to the crude fruit. It was no unnatural conclusion that they might equally be used for the purposes of making wine. Experiments were accordingly instituted in France for this purpose, and they have been repeated here with success. From vine-leaves, water, and sugar, wines have been thus produced in no respect differing from the produce of the immature fruit, and consequently resembling wines of foreign growth." The leaves of the claret vine produce

wine of a delicate red colour. The leaves may be taken at any period from vines which have been cultivated for this purpose, and from which no fruit is expected. The leaves are best when young, and must be plucked with their stems. Forty or fifty pounds of such leaves being introduced into a tub of sufficient capacity, seven or eight gallons of boiling water are to be poured on them, in which they are to infuse for twenty-four hours. The liquor being poured off, the leaves must be pressed in a press of considerable power; and being subsequently washed with an additional gallon of water, they are again to be pressed. The sugar, varying from twenty-five to thirty pounds, is then to be added to the mixed liquors; and the quantity being made up to ten gallons and a half, the process recommended in the case of gooseberries is to be followed.

Raisin Wine.

Take twenty-eight pounds of raisins picked from the stalks. Let them be chopped into small bits with any proper instrument, and thrown into a deep tub or bucket. Pour on them three gallons of tolerably hot water, and let them stand for twelve hours. Throw the whole into a hair-cloth or canvass bag, and with a press of sufficient power force out the juice. On the marc pour two gallons more of hot water, and after twelve hours press out as before. Mix the two liquors; add three pounds of white sugar, and dissolve it perfectly. A fermentation will set in; when over, the liquor is to be racked into a clean cask, and left bunged up for three months, after which it is to be again racked. A quarter of an ounce of isinglass dissolved in a little water or wine is to be mixed with it, and the whole returned into the cask. Being closely bunged, it is to remain for twelve months, after which it may be bottled. The cask should be full.

Wine from unripe Grapes.

As no bad flavour is communicated by the husk or stem of the grape, this fruit may be used in any stage

of immaturity in which it is most conveniently obtained. Grapes of different degrees of maturation may even be mixed together; nor is it requisite to attend to the selection of any particular variety. If fruit raised out of doors is to be used, it will be preferable to wait till the grapes show a tendency to ripen, or till the advance of the cold season shows that no farther change can be expected. The proportions and treatment are precisely similar to those laid down for the gooseberry. (Macculloch).

Section IV.

CIDER AND PERRY.

These favourite beverages are, through some singular fastidiousness of arrangement, generally separated from the class of liquors called *wines*. The fermented liquors made from the juice of currants, gooseberries, and various other fruits, to which sugar is added; and from the juice of grapes to which sugar is not added, or at least seldom, are all named wines. Why the fermented juices of apples and pears should not be admitted to the same class is not obvious: in their nature they seem to be effervescing wines, just as much as champagne, although not so strong, and more sour and sweet. It will suffice to describe the process for making cider; for the same description will equally apply to perry.

The apple consists of woody fibre, as its solid fabric, containing various substances; sugar, water, malic acid, and yest, are the chief. The yest, as in the grape, is not in contact with the sugar and water; but is contained in different depositories: hence the juice while in the apple does not ferment.

In an early number of the Philosophical Transactions, we find the following observations on the apple trees from which the best cider can be obtained, in a communication from Mr. Richard Reed of Herefordshire, the county which, of all others in England, affords the best produce. "The best cider I ever had was red-streake

grafted on a gennet-moyle stock: for as those kinds agree best, and the trees so grafted seldom canker, so the fruit is far milder, and, being ripe, both rich and large, and good to eat; and the cider is smoother, and abates in strength and harshness of that on the crab, and needs less of mellowing before making, the stock in some degree altering and reclaiming, the nature of the fruit. For an apple is best grafted on a crab, which gives acrimony and quickness to the fruit, so a crab (and the red streake is no other) grafted on an apple, receives thence gentleness, softness, size, and an excellent alloy to the sharpness, and (as Mr. Evelyn calls it) the wickedness of the fruit."*

In a later volume of the Philosophical Transactions, we find a paper communicated by the Rev. H. Miles, "on some Improvements which may be made in Cider and Perry," from which it would appear that so much care in the selection of the fruit is by no means necessary. The design of the paper is to invite gentlemen, after the example of a practice that has long obtained in Herefordshire, to attempt an improvement of their waste lands, by planting such kind of fruit trees, as are mentioned, in hedges and all barren places. The following is the account given in the abridgment of the Transactions by Hutton, &c.

Extract from a manuscript written 1657-8, by Dr. John Beale, F.R.S. concerning an excellent liquor made of a mixture of rough pears and crabs. The author undertakes to evince "that crabs and wild pears, such as grow in the wildest and barren clifts, and on hills, make the richest, strongest, the most pleasant and lasting wines that England yet yields, or is ever like to yield." — "I have so well proved it already," says he "by so many hundred experiments in Herefordshire, that wise men tell me, that these parts of England are some hundred thousand pounds sterling the better for the knowledge of it." He mentions of these kinds of austere fruit, the Barland pear and the Bromsbury crab, and intimates

* Philosoph. Trans. by Hutton, &c. i. 581.

"that though the discovery of them was but then lately made, yet they had gotten a great reputation." He adds "the croft crab and white or red horse-pear excel them, and all others known or spoken of in other countries." Of the red horse-pear of Felton or Longland, he observes "that it has a pleasant masculine vigour, especially in dry grounds, and has a peculiar quality to overcome all blasts." Of the quality of the fruits he says, "such is the effect which the austerity has on the mouth on tasting the liquor, that the rustics declare it is as if the roof were filed away; and that neither man nor beast care to touch one of these pears, though ever so ripe." Of the pear called *imny-winter*, which grows about Rosse in that county, he observes "that it is of no use but for cider; that if a thief steal it, he would incur a speedy vengeance, it being a furious purger; but being joined with well chosen crabs, and reserved to a due maturity, becomes richer than a good French wine; but if drank before the time, it stupefies the roof of the mouth, assaults the brain, and purges more violently than a Galenist." Of the quality of the liquor he says, "according as it is managed, it proves strong Rhenish, Bacrack, yea, pleasant Canary, sugared of itself, or as rough as the fiercest Greek wine, opening or binding, holding one, two, three, or more years, so that no mortal can yet say at what age it is past the best. This we can say that we have kept it until it burn as quickly as sack, draws the flame like naphtha, and fires the stomach like aqua vitæ." He says "that he made trial at his own house with wine d'Hay, by a merchant of Bristol highly extolled, which compared with a liquor made of crabs and wild pears was so much inferior, in the judgment of all, that the comparison was ridiculous." And he further relates "that a great planter had then by him many tuns of liquor made with this mixture of fruit, that carried the applause from all palates; and that all his common hedges yielded him store of the said fruit." To recommend this easiest, cheapest, and most profitable kind of agriculture, as he calls it, he says "that the best

of these pears grow on very bare and sandy hills, or vales; crabs on any mound or bank that may be raised on a heath; that one pear tree ordinarily bears yearly forty or seventy gallons statute-measure, and some seven times as much. Since I undertook this argument, we made in one year 50,000 hogsheads, and this shows the hardiness of the fruit. Let our noble patriots weigh this, the art of raising store of rich wines on our common arable, on our hills, and waste grounds, the charge a trifle, the pains small, the profit incredible. For some uses the shadow of the orchard brings on the grass a fortnight the sooner, as commonly for ewes and lambs." *

These quotations are of great consequence. If the facts are truly stated, and I have no doubt that they are, as they correspond with my own experience to be stated hereafter, they prove how much in error those persons are who are particularly solicitous about the nature and quality of the apple or pear which is to be made use of for the manufacture of cider or perry. I by no means wish to be understood to mean that mere crabs will produce liquor which will prove pleasing to all palates; but that mere crab cider will please many; that by peculiar management it may be fermented down into a strong spirituous liquor; and that a large intermixture of crabs with apples of any other quality or pears will afford excellent and well-flavoured liquor.

The instructions given by Mr. Knight for making cider are, as far as they go, excellent; and before we enter any further into the subject, it may be necessary to lay them before the reader, who will be much struck with the difference of his statements.

"The merit of cider will always depend on the proper separation of the fruits: those only whose fruit is yellow, or yellow mixed with red, are proper to make the fine cider; those whose flesh and rind are green are very inferior. The fruit should remain on the tree until a slight shake will disengage them. Each kind should be kept separate in layers, eight or ten inches

* Phil. Trans. by Hutton, &c. ix. 165. anno 1745.

thick, exposed to the sun and air, and not pressed until they are perfectly mellow, without being decayed. Except the fruit can be exposed to a free current of air, they had better not be put under cover; but where this can be effected it is an improvement. Fruit continues to improve as long as to increase in colour without decaying, and before grinding they should be carefully examined, and any green or decayed fruit carefully separated from them; this will not only greatly improve the flavour of the cider, but prevent too great a degree of fermentation. Each kind of fruit should be ground separately, or mixed only with such as become ripe at the same time. By a judicious mixture of fruits the requisite qualities of richness, astringency, and flavour are obtained, which seldom can be had from one kind. In grinding, the fruit should be so reduced that the rind and kernel should be scarcely discernible. In such a complete mixture it seems probable that new elective attractions will be exerted, and compounds formed which did not exist previously to the fruit being placed under the roller. The process of slow grinding with free access of air gives the cider good qualities it did not possess before, probably by the absorption of oxygen. To procure very fine cider the fruit should be ground and pressed imperfectly, and the pulp spread as thin as possible, exposed to the air, and frequently turned during twenty-four hours, to obtain as large an absorption of air as possible. The pulp should be ground again, and the liquor formerly expressed added to, by which the liquor will acquire an increase of strength and richness. Whilst fermentation is proceeding the casks should be kept in the open air, or in airy sheds, and racked when it becomes clear: before this it is useless to rack, as the fermentation begins again. The instant fermentation stops, which may be known by the clearness of the liquor, it should be drawn off into a clean cask, and the lees put into flannel bags: the clear liquor from those should be returned into the cask; but it must have great attention paid to it, that it has not the least ten-

dency to become acetous, which it will frequently do in forty-eight hours; if so, it must on no account be added to the cider in the cask. If the cider after being racked remains bright and quiet, nothing more is to be done until spring; but if a scum collects on the surface, it must be immediately racked off into another cask, as this would produce bad effects if suffered to sink. If a disposition to ferment with violence again appears, it will be necessary to rack off from one cask to another as often as a hissing noise is heard. When cider is not disposed to ferment, it is probable that a small quantity of yest or the lees of good cider will produce that effect, which is desirable before the commencement of cold weather. In April the cider should be racked into the casks in which it is to remain. They should be previously well scalded and dried, and filled nearly to the bung, and stopped closely, if all danger of fermentation is over; but not so tightly as to endanger the casks in case of a renewed fermentation. Cider which has been made from good fruits, and properly manufactured, will retain a considerable portion of sweetness in the cask for three or four years. It is usually in the best state to be bottled at two years old, when it will become brisk and sparkling, and if it possesses much richness will remain with scarcely any change for twenty or thirty years, if well corked. The specific gravity of the juice of any apple recently expressed indicates with considerable accuracy the strength of the future cider."

The care directed by Mr. Knight for selecting and collecting the fruit may be necessary for producing the kind of cider that is valued in certain districts; but that it is not essential for obtaining excellent cider, for very general use, is abundantly proved by the observations which have been already quoted, and by the practice in Ireland. As to his manner of conducting the fermentation and his after-treatment, there can be no doubt of its conduciveness to produce a certain quality of cider; but much less delicacy of treatment, and less rigid observance of his precautions, will produce a beverage of a

degree of excellence which need scarcely be surpassed. Beside, we must recollect that as cider is not valued for the quantity of alcohol which it contains, but for its delightful *mélange* of sweetness, sourness, and sub-acerbity, extent of fermentation is of little importance, provided that the liquor has been so far decomposed as to furnish sufficient carbonic acid to saturate the water of the apple juice. It is then sprightly, and sufficiently so for a state intermediate between bottled cider in high order and draught cider. It has this advantage also, that if left exposed to the air for a short time during its use at table, it does not become in the least vapid, for it continues to ferment. The chief objection to the use of cider in this state is, that it is not clear. This is a defect which offends the eye, but scarcely the taste, unless the fermentation is altogether too young, and that the liquor is actually loaded with turbidity. And we must remember, that age and transparency are not requisites for the excellence of cider in all countries, it being in some parts of the world quite common to use it while half fermented and a little turbid.

The chief machinery necessary for the manufacture of cider are, a mill for grinding the apples, and a press for separating the juice; along with a proper supply of vessels for the fermentation, racking, and storing. In Herefordshire, the mill made use of is the common vertical millstone moving in a circular stone trough. The millstone should be made of granite, but by no means of limestone, as this is readily acted on by the malic acid. It may be four feet in diameter, and one foot in thickness. The stone moves vertically in the trough where the apples are strewed, one apple in depth at first. It is moved round by a horse, the principle being the same as the crushing mill, commonly used for a variety of purposes.

In Ireland, a very different mill is made use of. It is composed of two horizontal rollers of hard wood placed about the distance of one or two inches asunder, and so connected by toothed wheels at their ends, that when

set in motion they move in directions contrary to each other. Into each of these wooden cylinders are hammered square studs of iron, like nail-rod iron, much in the manner in which the pins are driven into the cylinder of a barrel-organ, forming complete and regular ranks all round the cylinder. But these ranks are so disposed, that the pins of one cylinder do not oppose the pins of the other, but pass immediately beside them or through them. Thus, if there be 100 ranks on each cylinder, the distance between each rank on one cylinder will be just enough to permit a rank on the other cylinder to pass through. It is obvious from this arrangement, that an apple thrown between the two cylinders turning in contrary directions will be torn into minute pieces in a moment. Yet this mill never reduces the apples to so smooth a pulp as Mr. Knight declares to be necessary. And it is even common to beat the pulp, with wooden pestles, after it has passed through the mill, so as to reduce it much smaller. The iron pins remain so short a time in contact with the apple juice that no impregnation takes place by the metal.

The press in Herefordshire is a modification of the common screw press, the screw being vertical and the pressing boards horizontal. Into the cross-holes of the screw levers are inserted. The pulp is contained in hair-cloth bags.

In Ireland, the press is altogether different. A floor of strong planks, set on stone masonry, is first constructed. Round this floor a rim of plank is raised to prevent the juice from running to waste. A vertical stout pillar of wood stands beside the floor, into which is movably inserted one end of a lever of the second order. At the other end of the lever is applied a sufficient manual power; and in the proper situation the lever is made to act on pressing boards, between which and the floor are placed the hair-cloth bags containing the pulp. The lever is kept to its duty by causing the end forced down by the assistants to be caught in a fork, and held there by a pin in a hole, until forced below the next hole.

It is not considered a good plan to press out the juice from the apples as soon as they are ground in the mill. According to the season and degree of ripeness the juice should remain one, two, or three days on the *marc* or residue. If the season be summer and the fruit not ripe, one day will be sufficient; if autumn, and the fruit quite ripe, three days may be allowed. There are several reasons for this mode of proceeding: because by allowing the juice to stand on the *marc*, the flavour of the pippin is extracted; the fermentation is the sooner excited; and the juice is more easily and copiously separated by the press. But in warm weather, if the juice be suffered to remain too long on the marc, the vinous fermentation is endangered, and a stage partaking of both the acetous and putrefactive kind is likely to set in. While the apple is yet unripe, its juice when extracted will contain an abundance of natural yest; and hence the action of the additional portion of yest remaining in the *marc* would be too energetic. Experience proves that these positions are well founded: for apple-juice extracted from fruit not quite ripe, in summer begins to ferment in a few hours after it has been pressed; whereas the juice of perfectly ripe apples, such as we obtain in the middle of autumn, will not ferment for several days, even when kept in a warm room.

In Herefordshire and Devonshire they are very solicitous about the quality of the apple from which cider is to be made. In parts of Ireland, where as fine cider is made as in any part of the world, and where the common English cider would not be drank, owing to peculiarity of taste, they pay very little attention to the nature of the apple. They conceive that a mixture of every sort of apple produces the best cider; and they always admit a proportion of crabs. I have made cider from all kinds of apples; and although I am convinced that the quality of the apple makes some difference in the quality of the cider, I do not believe that it is of near so much importance as the manipulation of the process. I have made good

cider from wildings, and almost as good from nearly thorough-bred crabs. The taste, it is true, is very sour, and less sweet than English cider: but this is matter of fancy; and a relish for rough cider once acquired, the sweet kind loses much of its attractions. Owing to a considerable admixture of crabs, the Irish cider is always more sour than the English, and this is a quality, when not too predominant, for which it is valued by the natives.

As soon as the apple-pulp is brought from the mill, if it be allowed to drain without pressure, the juice which thus flows spontaneously will afford much better cider; and the same observation applies to the wine made from the spontaneous flowings of the grape. The pulp, by pressure, will still afford an excellent cider. The *marc* which remains after pressure, if infused in boiling water, allowed to remain for two days, and then pressed out, will afford a liquor which when fermented is an inferior kind of cider formerly called *ciderkin;* this is used as a common drink, or for servants. At present it is called water-cider.

For making perry, the pears should not be quite ripe; and the admixture of some crabs will add much to the sprightliness of the taste. Perry is generally considered inferior to cider. It is thought by some to resemble champagne more than gooseberry-wine does; and it is said, when of the best quality, to have been at times sold instead of champagne. The produce of pears is greater than that of apples.

It will save some subsequent trouble if, in the pressing out the juice, the action of the press be applied gradually, and very slowly increased. In this way the juice, at first running muddy, will at length come off perfectly transparent.

The changes which take place during the process for making cider are well characterised by the phenomena. If an apple be cut, it at first appears perfectly white; but after a while it becomes brownish. In the same manner, if a quantity of apples be suddenly crushed, and

as suddenly expressed, the juice is at first transparent and little coloured: but after exposure to the air its colour deepens to brownish yellow; it becomes muddy; it runs into the vinous fermentation, during which the muddiness cracks in streaks, begins to subside, and at length, when the fermentation is nearly over, the matter which caused the muddiness all collects at the bottom in the form of a subtile sediment of a brownish colour.

All this might be explained in the following manner: —While the apple is yet whole, the sugar dissolved in the juice is not in contact with the yest, and therefore there is no fermentation excited by their co-existence. Or we may suppose that the yest is not active until it is exposed to the action of the air, and has absorbed oxygen, as was found to be the case with grape-must by Gay-Lussac. The apple being encased in a tough impermeable skin is protected from the contact of the atmosphere. But when the juice is expressed, the natural yest, which up to this time was inactive, and was held dissolved in the juice, now absorbs oxygen, becomes insoluble, excites fermentation, separates in flocks, and subsides as a sediment. Meanwhile the saccharine solution has undergone the changes already described in the chapter on the vinous fermentation, the results being carbonic acid and alcohol.

The fermentation of cider should never be allowed to be complete. It is valued for its sweetness: if the sugar be all decomposed, there is certainly a greater portion of alcohol produced, but this is an ingredient little valued in cider. When the fermentation is complete, the liquor is sour and rough, and by no means desirable. In this state it is sometimes kept for the use of servants, because in its preparation it gives so much less trouble. I have converted apple-juice into a real dry wine by urging the fermentation until all the sweetness disappeared: the wine resembled the worst kind of Cape Madeira, but not until it had been two years in bottle.

In any case the quantity of alcohol is inconsiderable; and when it is distilled off, unless frequently and carefully rectified, it is of an exceedingly bad quality. Vine-

gar is a more abundant ingredient in cider, and the more especially if it have been permitted to remain long on its own deposit of yest, or on its *marc.* By long keeping in half-filled vessels, and sooner if the cider be weak, a total conversion into vinegar may be effected. This vinegar, when sufficiently formed, is of an excellent quality.

The average of several trials which I made of the quantity of juice obtainable from one hundred weight (112 pounds avoirdupois) of apples was eight gallons. The apples had, in all cases, been well crushed and pressed. One hundred weight of apples will be composed of about 600 in number when the apples are large, and of about six times that number when they are of the smallest size.

In summer, before the apple is ripe, the natural yest of the fruit seems to be by far more active than in autumn when it is perfectly ripe, even making allowance for the difference of temperature. From my trials I am induced to think that the cider made in the latter part of the summer is better in quality than that made at a more advanced period of the year, but that it requires more skill in the management of the fermentation. The juice pressed from the fruit not perfectly ripe, although sourish at first, becomes sweeter during the fermentation. The fermentation at this early part of the cider season is by far more active, and is completed in a much shorter space of time. I have completed the whole process from the pressing out of the juice to the bottling of the cider in the space of four days during summer; and in three other days it was fit for drinking, of a delightful flavour, highly effervescent, and almost perfectly transparent. When made in summer, it must be fermented in small, divided quantities: the fermentation of much at a time endangers the spoiling of the whole, by turning it into vinegar, or even communicating a putrescent smell. It will be also necessary to rack it off continually from the lees, so as to moderate the fermentation. Lately it has been announced that finely powdered charcoal, thrown in

and well mixed, has the effect of checking inordinate fermentation of cider, and that it communicates no bad taste. The test by which we may know when the fermentation is completed is the clearing of the liquor in consequence of the subsidence of the flocks or muddiness. While carbonic acid continues to be extricated rapidly, the bubbles, by their ascent, prevent the subsidence of the sediment. When it is perceived that the liquor is clear, it may also be inferred that it is tranquil, and then it should be decanted from the yest, and bunged up in a cask with a vent-peg, to be opened occasionally, to permit the discharge of carbonic acid, which will continue to be formed for a considerable time. The cask will be the best mode of keeping the cider, if it is to be preserved for a length of time: but if it be intended for speedy consumption, it should be bottled as soon as it is clear, and the bottles kept on their sides for a week, when the cider will be found in high order and excellent.

It is, however, so much more easy to manage the process towards the latter end of autumn, that the months of October and November are always preferred. At this season the yest of the apple is by no means so active; and its activity is still farther diminished by the reduced temperature. That the yest is really less active in its nature appears from the fact that exciting an artificial summer temperature in the liquor does not produce an immediate fermentation, and sometimes not, even for several days; although the juice expressed in summer begins to ferment almost as soon as obtained. In autumn the fermentation is languid and slow: it takes a vast deal more time in running through its stages; it clears more slowly; and will remain in wood or in glass with much less risk of bursting. In my processes for making cider, I found that the sweetest apples were far from affording the best cider. Were I to consider nothing but flavour, I would prefer to use two thirds of sweet apples, including all those used as eating apples, and one third of wildings, or even the most degenerate crabs. The latter impart a pleasing liveliness to the

taste; and the acidity will be found not too great for many palates even if the quantity of crabs be one half. A due admixture of every quality of apple, perhaps, affords the best cider: that made altogether from crabs clears with great difficulty.

Keeping the apples for some time before they are ground does not deteriorate them for the purpose of making cider. This is a great advantage; for the windfalls may be collected day after day until a sufficiency be obtained to feed the mill.

Notwithstanding the extensive scale on which cider is generally manufactured in the cider countries, it is by no means necessary; and it is quite possible to make it in small quantities of as excellent a quality as is procurable in any other manner. The superabundant apples of a moderately large garden may be economically converted to this use, and without a great deal of trouble.

The machinery necessary for making cider on this domestic scale is simple, and easily obtainable at a small expense. The following answers the purpose as well as more costly apparatus: —

A tub is to be procured, made of strong staves: the bottom is to be much thicker than usual, and the peripheral edge of it must be at least half-inch thick, where it is let into the chimb. The iron hoops must be strong, especially the two lower ones on the chimb. This tub is to answer the purposes of a crushing-trough: it must sustain the strokes of a heavy pounder, and hence the necessity of its being made as strong as possible. The diameter of the bottom of the tub should be only eighteen inches; its height about the same.

The next article is the pounder. This is to be made of any hard wood. Its shape may be easily conceived, by imagining a cone about the size of an ordinary loaf of sugar, with a handle, proceeding from its apex, of about four feet in length. The base of the cone should be perfectly flat.

The press which will be found most convenient is the common square clothes-press. It consists of a rectan-

gular horizontal board three feet in length, a foot and a half in breadth, and at least four inches in thickness. At each end of this, and midway in the breadth, is erected a perpendicular square pillar, the transverse section of which is about four inches square: the height of each pillar is three feet. From the top of one pillar to the other is extended a cross bar of considerable scantling, not under six inches square, and through the middle of this is a hole with a concave screw, which receives the convex screw that constitutes the press. This perpendicular convex screw is attached at its lower end to a pressing board, which slides up and down between the two pillars, and has had square pieces cut out of its ends to receive the pillars, which by this contrivance keep it always in its place, while it follows the screw in its ascent or descent. The pressing board follows the screw, because the latter is so attached that it can turn freely in the pressing board, but cannot be drawn out. The pressing board is made equally thick with the rectangular board which constitutes the basis of the whole press. The screw, near where it is inserted into the pressing board, is made to swell into a bulb; and through this are two cross holes to admit an iron bar, for the purpose of acting as a lever in working the press. The whole is made of hard wood, firmly put together by dove-tails, and strengthened with iron cramps. The pressing board may be screwed down ever until it meet the bottom board; or it may be screwed up until it arrive at the top cross bar.

It is obvious, from the construction of this press, that if a bag of apple-pulp be submitted to its action, the juice will be forced out, but will run over its bottom board, and go to waste. In order to prevent this, a tin tray is made use of. This tray is rectangular, its area is a little less than that of the pressing board; it is shallow, its rims being only about two inches in height. Proceeding from one side, corresponding with the front of the press, a pipe emerges, so that whatever juice is forced through the bag of pulp will trickle down the

sides of the bag, will be received in the tray, and from this will flow through the pipe into a vessel placed beneath. The pipe is somewhat bent downwards, for the purpose of more freely delivering itself. It is to be observed that when a bag of pulp is to be pressed, it must be set standing on its end in the middle of the tray, and immediately under the screw above. The bag need not be tied round its mouth, but only folded over loosely; the pressing board will keep it sufficiently tight. The bag may be made of strong canvass or hair-cloth strongly sewed with double thread, or pack-thread. These are the chief articles of apparatus required for domestic cider-making; but some observations on the manner of conducting the process on the small scale may be necessary.

In crushing the apples, it will not answer to throw a number of them into the tub at once, and to commence pounding them. In this way vast labour would be expended in doing the business very badly. The proper mode is to throw in half a dozen first, and crush them well, which will be done with three or four strokes of the pounder; then another half dozen may be thrown in, and similarly treated. When there is so much pulp in the tub as to embarrass the further crushing of the fruit, it must be transferred into any other wooden vessel. The apples being all reduced to a tolerably small pulp, the next part of the process is to express the juice. The pulp thrown into the canvass bag is to be put under the press, and the juice forced out by a gradual and steadily urged action of the screw. In this way the juice may be drawn out perfectly transparent; but if the screw be urged suddenly, or by starts, the juice will be muddy, and the quantity of lees will occasion some loss of cider. It will be found also that when the pressing board can be forced no tighter, by leaving it untouched for a few minutes it will be easy to force it a little more; and by repetiting this process a much greater product of juice may be obtained than if force enough had been applied at first to endanger the press.

Having procured the necessary quantity of juice the next step is its fermentation. A very convenient fermenting apparatus will be the cask recommended in the section on domestic brewing: see page 207. The cask set on its end should be filled with apple-juice through the cork-hole at the top, and it may be left to ferment at the natural temperature of the air, should it be not under 60° in the shade. If the air be lower than that degree, the cask must be placed near the fire. In some hours (many will elapse if the month be November, and especially if it be cold for the season,) the fermentation commences, the head of yest rises up through the cork-hole, is retained by the chimb, falls back into liquor for the most part, and runs again into the cask, leaving the true yest on the top outside. This arrangement succeeds better in the beginning of September; but if the season be much more advanced, it will be better not to fill the cask entirely. In this way the yest will not be thrown out of the liquor, in which, at this cool season, its presence is so necessary to continue the languid fermentation that alone can be expected when the quantity is small. If there were some hundred gallons in one body under fermentation, the case would be different, and it might be an object to remove some of the yest, so as to restrain an inordinate action. In cider-making, any degree of fermentation that does more than generate a due quantity of carbonic acid, to impregnate the liquid for the purpose of taste, is injurious. It need not possess any intoxicating quality; an agreeable taste is the only quality to be expected from it: and this will be attained by fermenting until the excessive sweetness of the apple is removed, and is replaced by the sharpness of the carbonic acid, which just at that period will have been generated in sufficient quantity. The pleasing sourness of the malic acid will remain unaltered; and if the cider, when finished, comprises the three qualities of sweetness, sharpness, and acidity, without a predominance of any of them, the fermentation may be considered to have been of the most successful kind. The criteria,

by which the liquor may be known to be sufficiently fermented, have been already explained. In a large vessel, not full, a burning candle may be let down; if it burn there, the fermentation is over. As soon as the cider has ceased to ferment, it is to be drawn off the lees by boring a gimlet-hole at the bottom of the cask a little above the chimb. The liquor, as it runs out, is to be received in a clean cask, which when full is to be bunged, and may be kept for draught. Or, after remaining in this cask for two or three weeks, it may be drawn off and bottled, when it will soon get into good order. If the cider be made in cold weather it will require a longer time to clear; and the same will happen if there had been a very considerable ratio of crabs amogst the apples. A little dissolved isinglass added will soon clear it; but this tends to flatten. These, and a variety of minor circumstances, can be only learned and provided for by practice.

This apparatus will be found capable of doing a greater quantity of work than might be anticipated: one man employed in pounding the fruit, while another presses and otherwise assists, will produce ten gallons of juice in the day. The same apparatus succeeds admirably for bruising and pressing gooseberries, currants, raspberries, cherries, and various other fruits, from which domestic wines are manufactured. The press is the same as that used for pressing clothes, a convenience which no house should be without. The cost of such a one as has been above described is about three pounds. The tin tray will not give any ill taste or metallic impregnation to acid juices in the short time that they are passing through it; but if allowed to remain long in contact with the tin, a slight taste will be communicated. After the apples have been pressed, they may be economically pounded a second time, when they will afford a second product of juice.

CHAP. IX.

VINEGAR-MAKING.

In the chapter on fermentation, the general outline of the process and theory of making vinegar has been given. It will here be necessary to enter more into the details, and to describe the different modes by which it is obtained on the large scale, as well as on the scale which may be suitable to the purposes of domestic economy.

Section I.

VINEGAR OBTAINED BY FERMENTATION.

For making malt vinegar the process made use of is very like the first stages of the brewer's operations The malt is ground, and mashed with hot water. The wort is then cooled on the usual cooler, from which it is transferred to the fermenting tun, where being mixed with yest it ferments. The fermentation being over, the liquor is transferred to smaller vessels. These are arranged in an apartment kept warm by means of a stove that will be described hereafter: the temperature is maintained ever until the acetous fermentation is complete, and perfect vinegar is formed. This requires several months, more or less, according to the temperature and the strength of the liquid. It would require years to acetify it to the same degree, but that the souring is assisted by introducing into the casks, along with the wort, a quantity of the residuary fruit which has served for making domestic wines, or which is preserved by the vinegar-maker from one process to another in his own factory for this purpose. It is called *rape:* its use is to act as an acetous ferment, and thus inoculate the wash with sourness, it being well impregnated with vinegar, and continually kept so. Occasionally, also, other

vegetable substances impregnated with vinegar are used as acetous ferments. They all abridge the time necessary for acetification, which without them would be considerable; and the process would be more liable to failure.

Another mode of conducting the acetification is to transfer the wort, after it has undergone the vinous fermentation, into casks. The bung-holes of these are left open, and merely covered loosely with tiles. The casks are then exposed to sun and air for a great length of time, until the acetification is perfect. The introduction of stoves has superseded this mode. The stove has greatly abridged the time, and has rendered the process much less liable to failure.

In either method of proceeding, as soon as the vinegar has arrived at its greatest degree of sourness, the process should be stopped; for if continued the sourness would gradually diminish, and would at length totally disappear, and give place to putrescency. In order to prevent the occurrence of this injury, the vinegar must be racked off its lees, just as ale or wine would be; for the lees, in any of the three cases, will continue to act on the liquor greatly to its detriment unless removed. With a view of still more effectually removing this injurious matter, as well as for the purpose of rendering the vinegar transparent, a clearing process is adopted, the same in its principle and practice as that made use of of by the brewer or wine-maker. Isinglass is dissolved in a small quantity of the vinegar, and the solution is mixed with the remainder. The whole is then allowed to subside; and as soon as it is sufficiently clear, it is racked off, and is then fit for sale. Some manufacturers, however, do not use isinglass, but prefer clearing their vinegar by age. They conceive that by spontaneous subsidence they produce a better article for keeping.

On an average, it may be stated that one barrel of good malt is capable of producing thirty gallons of good house vinegar. The quantity of water used for the mashes should be calculated accordingly.

In the making of malt vinegar, a mixture of raw corn will neither lessen nor deteriorate the product. The grinding of the grist should be conducted precisely in the same manner as has been already described in the chapter on brewing. When raw corn is used, the heat of the water used in mashing must be lower than when malt alone is employed; and the rules laid down for brewing with mixed ana unmixed grists apply here equally. The relative quantity of grist and water are to be the same as already directed for making strong porter: the stronger the wort, the more acid will be the vinegar. Weak worts are soured in a shorter time, and at a lower temperature than when the wort is strong. The heat of the mash liquors, and the lengths drawn are to be the same as for strong porter; but they should be so calculated that no boiling down will be necessary. Hops have been recommended by some makers of vinegar as calculated to conduct the acetifying process to the end without any taint of putrescency; but if the stoving have been rightly managed there will be no taint of this kind, and hops will be but a needless expense. When the relative quantity of water to the grist has been too great, the strength of the wort may be brought up by the addition of sugar. The temperature of the wort when the yest is added must vary according to the temperature of the weather, as is the case in the brewing process. The heat maintained in the stove should vary with the strength of the wort: if the heat be such in the stove as will insure a temperature of 75° or 80° in the vinegar, it having been made of the saccharine strength already described, it will be sufficient. The length of time required for the maintenance of this temperature in the stove depends on the strength of the wort, and on the manner in which the vinous fermentation had been conducted. If the fermentation had been so managed as not to generate any acidity in the tun, it will require the longer time in the stove; and this will be an advantage. It is to be kept in mind that vinegar is formed from alcohol in this process: the greater the quantity of alcohol

present in the fermented wort, or rather wash, the greater will be the quantity of vinegar produced when the process is finished. This being the case, it is obvious of how much importance it is to conduct the vinous fermentation in such a way as is most conducive to the production of alcohol. But there is a limit. It has been shown in the chapter on fermentation that although, when wine and vinous liquors are converted into vinegar, it is the alcohol which suffers the change, we are not to infer from this that the more alcoholic the liquor the better it will be for vinegar. The truth is, that if it be too alcoholic it will not acetify at all; for the presence of much alcohol acts as a counteractor of the acetous fermentation.

The following is the process made use of, on the large scale, for preparing raisin vinegar, an article which sells at a higher price than malt vinegar, it being supposed to be a purer and better flavoured manufacture. Sugar is used as well as raisins to afford the fermentable basis. The fermenting tun is charged in the following manner:— To every hundred gallons of water, one hundred pounds of raisins and the same quantity of sugar are added, both of which are preferred of a bad quality for cheapness. The raisins are not bruised or cut; for they are used in so many subsequent processes that the whole of the soluble matter is eventually extracted from them. The mixture of water, raisins, and sugar is made at such temperature that the resulting degree will be 65° or 70°, according to circumstances. The mixture is then well roused up, and in some hours a fermentation spontaneously arises, without the addition of any yest; for the raisins contain the natural yest of the grape, and it is ready to become active when it is presented to the proper substance to act upon. The vinous fermentation then proceeds: the temperature rises more or less as the quantity is very large or moderate, but not at all if the quantity is small. It ought not to rise higher than 85°. The fermentation continues, according to the state of the weather, about three or four days. Meanwhile the liquor, which had marked perhaps

45 on Dicas's saccharometer, has now been attenuated to 15 or 10, below which it ought not to fall. The fermentation is then immediately checked, by racking off the wash into another tun, where it remains for two or three days. It is then let into cask-shaped vessels, each capable of holding about 300 gallons. These vessels are constructed as follows: — The cask stands on its end: at about two thirds of its whole height from the ground is placed a false bottom pierced with holes; and there is a lid which shuts down tolerably close on the top of the cask. All above the false bottom is filled with what is called *rape*, which in general means the residuum of any fruit when the juice is extracted; but in this case is raisins which had served originally for mashing with sugar and water, and which have parted with their saccharine matter. A long line of these casks being arranged close to each other, and each having a layer of rape on its false bottom, they are filled with the wash in the following manner: — The first is filled entirely; the second is filled only to the height of the false bottom; the third is filled entirely; and the fourth only to the false bottom; and so on alternately. This is the arrangement for the first day; but were the liquor left in this state for any considerable length of time it would become overheated, owing to the inordinate energy of the acetification, and the whole would run into the putrefactive fermentation. To prevent this, a change is made every day. On the second day, liquor is drawn out of the first or full cask until its surface falls as low as the false bottom: what is thus drawn out is poured into the second, which had been only full to the false bottom, but which with this addition is now entirely full. The same change is made in the whole series; and every day the liquor is made to circulate by these means. The apartment in which the series of casks is arranged is warmed by a fire kept constantly burning. The fireplace is a kind of furnace, the flue of which proceeds horizontally through the whole extent of the apartment or *stove*, as it is called; and having arrived at the end, it

turns round over the former, and proceeds back again the whole way until it arrives at the furnace, where it discharges into a vertical flue. Thus the whole heat extricated from the burning fuel is carried through the flue; it passes through the brick-work of which it is composed, and warms the air of the apartment. But as brick-work is a bad conductor of heat, this plan is less advisable than another which is adopted in other vinegar manufactories. The furnace is so contrived that it heats a metal conduit which opens in the cool air near the mouth of the furnace, and then passes on to the stove-room. The furnace heats the air in the metal conduit; the air being thus rarified ascends into the stove-room; cool air from without enters, becomes heated, and passes upwards. Thus a continual current is established, which both heats the stove and ventilates it at the same time, an object of the greatest consequence in preventing any putrid tendency. It is surprising how small a quantity of fuel affords the necessary temperature by this mode of applying it, and how bad a quality of fuel will succeed. I have seen a mixture of about equal parts of bad cinders and ashes answer for supplying the furnace, with a little coal occasionally. The proper temperature to be maintained is about 80°, and this must be kept up for about three months, when the vinegar will be sufficiently soured. The vinegar is then to be drawn off, a solution of isinglass is to be well mixed with it, and after due subsidence, the liquor, now perfectly clear and bright, is to be let into casks, which are to be bunged down. The article is then ready for sale.

The rape used in this process is kept for a succession of other processes: it will last for many years; and indeed ever until it is completely melted down and wasted away. Formerly, vinegar was made by leaving a saccharine solution in a cask which had frequently served for making vinegar. The timber became impregnated with vinegar; timber itself has some efficacy in exciting fermentation; and hence, thus impregnated, it became an active acetous ferment. Such also is, probably,

the action of the rape, it being composed of the woody matter of the raisin strongly pickled with vinegar. That it does act powerfully as an acetous ferment is obvious from the fact that the vinous liquor drawn from the fermenting tun will by itself remain sound and free from acidity for a great length of time; but in a day or two after it has been poured on the rape the sourness becomes perceptible. So energetic is it also, that if the liquid were not circulated every day in the manner described, it would in a short time putrefy. And if during the circulation, the rape lying on one of the false bottoms should be left dry, by the vinegar having been withdrawn and not replaced, the rape will heat in a few hours so hot that it can scarcely be endured by the hand: it will very speedily become putrid, and will in all respects resemble rotten manure. So great is the tendency to putrefaction, that if there is not free ventilation in the stove the vinegar will be inoculated with putrescency; and it will acquire an unpleasant smell and taste in a very short time.

As vinegar may be produced from all saccharine substances, and as the number of the latter is so considerable, it is obvious that the sources from which vinegar may be obtained must be numerous. Many of them are sufficiently economical. We may avail ourselves, for instance, of sugar itself, and form a vinegar from it pure in proportion as the sugar had been so. The following process succeeds well, and is so easily conducted, that it may be successfully adopted in domestic economy. It is often attempted by good housewives; but for want of attention to a few particulars, easily understood when pointed out, it does not always succeed.

To make sugar vinegar on the small scale, take eight pounds of the worst quality of loaf sugar: dissolve it in six gallons of hot water; introduce the solution into a deep vessel, which will be the better if it narrows towards the top. When the solution has cooled to about blood heat, mix intimatately with it about half a pint of the best and stiffest yest. If in summer, a fermentation

will spontaneously arise after a few hours, which will be known by the appearance of a scum of froth over the surface of the liquor. This will increase for a few days: minute air-bubbles will ascend from all parts of the liquor towards the surface; the sweetness will gradually lessen day after day; and at length it will disappear so perfectly that the taste will not be in the least sweet. As soon as this has happened, the fermentation which of late had been declining will be totally at an end. The head of froth, which is in fact yest, and will answer as such for other purposes, has partly at this period subsided to the bottom; but part still floats, and this ought to be removed with a scummer, or by other means. The vinous liquor is then to be decanted from the sediment in the bottom. By this time there will remain of the liquor about as much as will fill a five-gallon cask within two or three inches of its bung-hole, for it ought not to be quite full. The cask, with its bung-hole merely covered by a bit of slate or tile, is to be exposed either to the sun, or kept in a kitchen beside the fire, which is a preferable method, as a uniform temperature is thus kept up. After a few weeks, more or less according to the heat, the liquor will be found somewhat sour: the sourness will continually increase; and in about eight months it may perhaps be perfectly acetified. If the liquor be now decanted from a new sediment that has been deposited, which may be readily done by boring a gimlet-hole near the bottom, it will be found perhaps sufficiently transparent. If not, let about a quarter of an ounce of isinglass be dissolved in a sufficient quantity of the vinegar, and let the solution be mixed with all the rest. After agitation, let the vessel rest: introduce it into the same cask, well cleansed; bung it up, and leave it at rest for a fortnight. The vinegar will now be perfectly transparent: it will have very little colour; and it may be drawn off at the gimlet-hole, and bottled. The bottles ought to be kept in a cool place; and if they should show symptoms of change after some months, such as the formation of a gelatinous substance

in the vinegar, the latter should be decanted off, strained, and again bottled. This process is to be repeated as often as the coagulum appears; and troublesome as it may be, it must be done with every vinegar, whether home-made or purchased. The formation of the coagulum is not a defect in the domestic process, but is incidental to all vinegars made by fermentation: it is less likely to occur in wine vinegar, because it is the purest species, and in large volumes of vinegar than in small.

It has been stated, that when the yest is added to the solution of sugar, a fermentation will spontaneously arise if the season be summer. If it be not summer, especially if it be winter, it will be necessary to keep the liquor beside the fire during the whole period of the vinous fermentation, as well as during the progress of acetification.

Vinegar made according to the foregoing method may be considered as of medium strength: it is by no means the strongest that it is possible to procure. A stronger vinegar may be made by using a greater proportion of sugar in the first instance. But much more time will be required for acetification, and there is a greater chance of failure in the hands of the inexperienced; in other words, the application of scientific knowledge becomes necessary to overcome the difficulties, and obviate the risks which may occur. There are two ways, which may be practised, of increasing the strength of vinegar made according to the foregoing or any other process; they are equally simple, and certain of success. The first was recommended by Homberg, and was founded on a fact discovered by Stahl.

Expose a vessel of any kind containing common vinegar to the cold of a very frosty night; next morning a quantity of ice will be formed in it, which, if removed and thawed, will be found to be pure water. The vinegar being freed from so much water, will, consequently, be more acid than before. The same process may be repeated on it so as to obtain a new portion of ice as

often as is necessary, until a sufficiency of water has been removed, and the vinegar has been sufficiently concentrated.* A kind of analysis of the vinegar thus takes place, the water being separated much in the same manner as happens when sea-water is frozen; for the ice consists of fresh water, and what remains unfrozen is much more salt than before. In the case of vinegar, however, we must observe, that the more frequently it has been frozen the greater will the actual loss be; for although the first portions of ice are water, the latter portions will become more and more acid: hence the concentration must be stopped at a certain point. In this way exceedingly strong vinegar may be obtained from the weakest specimens.

The other mode of strengthening vinegar is to dissolve sugar in it. The sugar either passes at once into vinegar, or undergoes the previous process of the vinous fermentation, which is improbable. Be the manner of the change what it may, it is certain that the sourness of the vinegar very soon begins to increase: after some weeks the taste of the sugar cannot be recognised, and the acidity of the vinegar is much augmented. It will not answer to add too much sugar at once, for the very excess would prevent its own acetification. The temperature ought to be kept up. According to M. Cadet-Gassicourt, good vinegar may be at once made by mixing together 124 parts of sugar, 868 parts of water, and 80 parts of brewer's yest or baker's leaven, exposing them to the air, and filtering the liquor at the end of a month.

Very strong vinegars are made in France by adding some concentrated acetic acid and alcohol to the vinegar of Orleans. Such are sold at a high price. †

Excellent vinegar may be obtained from the juice of various fruits. There are some fruits, however, the juice of which is so little saccharine, that sugar must be added in order to produce sufficient acidity: this is

* Memoirs of French Academy, 1739.
† Thenard, Traité de Chimie, iii. 496.

the case, for instance, with currants and gooseberries, which are commonly used for making fruit vinegar. For the sake of economy it is usual to employ the fruit for the double purpose of making wine and vinegar. For the former the juice is made use of, for the latter the pulp and husk are employed; and with this intent they are infused in hot water and strained; to the strained liquor sugar and yest are added, and the fermentation is allowed to proceed in the manner already described. There is little economy or advantage of any kind in these methods.

The juice of good apples contains a sufficiency of sugar to afford tolerably good vinegar without any addition. Cider may be acetified by introducing it into a cask which it does not quite fill, and which has served previously for holding vinegar, although this latter condition is not altogether indispensable. If the cask be placed in a warm situation, its bung-hole being merely covered by some loose covering, the cider will soon begin to sour, and after six months or more it will be converted into vinegar. It should then be racked off, and kept either in bottles or a cask, taking care to decant it whenever a coagulum appears. Cider-vinegar is particularly subject to this coagulum. If the cider had been strong, the vinegar will be proportionately so, and, indeed, will be strong enough for all purposes: in this case a greater length of time will be required for acetification, probably a year or even two might be necessary. Should the vinegar prove weak, it may be strengthened by the cautious addition of small quantities of sugar in the manner already described, waiting for the acetification of each addition before any more is added. Cider that has not kept well and has soured will be the most economical and convenient for conversion into vinegar; the conversion will also be effected in a shorter space of time. Any sort of wine, whether foreign or domestic, that has not turned out well, may also be readily converted into vinegar, by infusing it on pounded gooseberries, currants, raisins, or the *marc* remaining after

any wine-making process; then straining it off, and exposing it, as already described, to air and sufficient temperature.

In France vinegar is made from poor wine; and it is considered purer than any other kind, and is generally stronger than the vinegar of this country. The following is given in an early volume of the Philosophical Transactions, as the method practised in France: — "They take two large casks, within each of which they put at the bottom a trevet, which must be one foot high, and as large as the size of the cask permits; on this trevet they put vine twigs, whereon they lay a substance called rape, with which they fill both vessels within half a foot of the top. This *rape* is nothing but the wood or stalks of the clusters of grapes dried and freed from the fruit. The trevet and the vine branches are put at the bottom of the casks, only to keep the rape from settling at the bottom: it is this rape which alone heats and sours the wine. The two vessels being almost quite filled with the rape, one of them is filled up with wine, and the other only half full for the time; and every day they draw by a cock half the wine that is in the full vessel, therewith quite to fill up the other that is but half full, observing interchangeable turns of filling and unfilling the vessels. Ordinarily, at the end of two or three days, the half-filled vessel begins to heat, and this heat augments for several days successively, continuing to do so till the vinegar is perfectly made; and the workmen know that the vinegar is made by the ceasing of the heat. In summer it is a work of fifteen days; in winter it proceeds more slowly, and that according to the degree of cold weather.

"When the weather is hottest the wine must be drawn twice a day, to put it out of one vessel into the other. It is only the half-filled cask that heats, and as soon as they have done filling up, its heat is choked and stopped for the time, and the other cask, which is unfilled, begins to heat. The full vessel is quite open at the top, but a wooden cover is put on the

vessel that is but half full. The best wine makes the best vinegar; but yet they make good vinegar of wine that is turned.

"The wine in changing leaves a certain grease, which sticks partly to the sides of the cask (and that they take care to remove clean away), partly to the rape, so that if they cleanse not the rape from it almost every year once, the wine turns into a whitish liquor, which is neither wine nor vinegar. At the time when they pour the wine out of one vessel into the other, a scum arises on the top of the vessel, which must be carefully taken away. In the casks which have never served for this purpose before, the vinegar is made more slowly than in such as have been used.

"As soon as the rape is separated from its grapes, which is done immediately after vintage, it is carefully put up in barrels, lest it take air and heat itself, and be spoiled. Rape will serve a year more or less, provided care be taken to clear away every morning with a piece of linen the grease that is on the sides of the vessel, and with a little broom that which swims on the top of the liquor. The rape may be freed from its grease with water, rubbing it between the hands." *

This process is almost exactly the same as that given by Boerhaave in his Elements of Chemistry, and is one of the best known. It illustrates the theory of acetous ferments.

MM. Prozet and Parmentier give the following account of the manner of making vinegar at Orleans, a place famous for the excellence of its vinegars:—The vats which are employed contain about eighty-eight imperial gallons; those which have already served for the preparation of vinegar are preferred: they are called (*mères de vinaigre*) *mothers of vinegar*. On the upper part each has an opening of $2\frac{1}{8}$ inches diameter, which is never closed. They are generally arranged in three ranks, one above another, in an apartment which is without any fire in summer, but in winter is heated to the temperature

* Hutton, Shaw, and Pearson's Phil. Trans. abridged, i. 470.

of 72° or 77°. Into each vat or *mother* are poured twenty-two gallons of good vinegar boiling. Eight days after, 2·2 gallons of depurated wine are poured in: in eight days more the same quantity of wine is again added, and so on until the vats are full. In fifteen days after this, the vinegar is made; nevertheless they draw off but one half of the contents of each vat. To each vat they then add 2·2 gallons of wine every eight days, as already described. But it sometimes happens that the quantity of wine added is more or less, and the intervals at which the new portions are poured on differ from those described. All this depends on the progress of fermentation. To learn the state of the liquor, the vinegar-maker plunges a staff down into the vat: he judges that the fermentation is active when the staff comes up covered with scum or *flower of vinegar;* a fresh portion of wine is then added. Such is the process followed in France for making the best wine-vinegar.

There are two kinds of wine-vinegar prepared in France called white and red. The white is made with white wine, or with red wine soured on the *marc* of white grapes. The red is made by the acetification of red wine.

In order to deprive red vinegars, even the deepest, of their colour, M. Figuier employs animal charcoal, that is, bones calcined out of contact of air until they become black. What is called in commerce *ivory black* is prepared in this way. It is, however, to be observed, that bones calcined to blackness are not animal charcoal, although they contain it; they also contain phosphate and carbonate of lime. By digestion in dilute muriatic acid these two earthy salts are removed, and the animal charcoal remains tolerably pure.

The following experiment of M. Figuier proves the effect of animal charcoal in the decoloration of deep vinegars:—A litre (2·11 wine pints) of red vinegar and 45 grammes (690 grains) of bone charcoal were left to act on each other in the cold, in a glass vessel, often shaking them for twenty-four hours. The vinegar soon

began to grow pale, and in two or three days it became quite colourless. It had lost neither taste, smell, nor acidity. He then prepared some pure animal charcoal by washing away the earthy salts with muriatic acid. A litre of vinegar will only require 24 grammes (470 grains) of this animal charcoal in order to completely deprive it of colour.*

Milk has the property not only of removing the colour from red vinegars, but at the same time of clarifying them. For this purpose a very small quantity is required: they are to be shaken together and allowed to deposit. The sediment is easily separated.†

Vinegar is purified for pharmaceutical purposes by distillation. If the distillation be conducted in a common copper-headed still and pewter worm, the resulting vinegar will be impregnated with both of these metals, if there was any quantity of oxide on the surfaces; if not, the vinegar will not in the least degree act on the clean metallic surfaces. In the distillation of vinegar, the first product is alcohol: for the original acetification is never so perfect as to convert the whole of the alcohol into vinegar. The alcohol comes over with a little vinegar and much water. By rectification from hydrate of lime, used barely in saturating quantity, alcohol will be produced in such quantity as will generally pay the expense of the fuel. After the alcohol very weak vinegar comes over. By degrees the vinegar comes over more and more strong, until the whole procurable quantity has been obtained. But, unfortunately, in proportion as it comes over strong, it acquires a less fragrant smell, and a less agreeable taste. At length the smell and taste become decidedly empyreumatic; and if we still urge the distillation, we obtain pyroligneous acid precisely the same in all its characters as that obtained by the distillation of wood. The same tar makes its appearance, and the same inflammable gases. At this time the acid which comes over is exceedingly strong.

* Annales de Chim lxxix 75.
† Thenard, Traité de Chimie, iii. 495.

The origin of the empyreuma is the great quantity of vegetable matter, which the original vinegar contained, consisting chiefly of what is vaguely termed extractive matter, and some unaltered saccharine matter, with one or two other ingredients. These not being volatile, their relative quantity is continually increasing, until at length the contents of the still become so thick, that burning is the consequence, and the same products make their appearance as when any other vegetable substance, which is not volatile, is exposed to a higher temperature than its constitution can endure without a subversion of its affinities. It is plain, therefore, that the method of purifying vinegar by distillation is uneconomical, as the strong part of the vinegar remains in the still until it is injured, and the strongest part until it is actually destroyed. In the distillation we find that the whole of its vegetable matter is not detained in the still; for the vinegar which comes over has carried a portion along with it, and is easily detected. This is found a great inconvenience when the vinegar is used for pharmaceutical purposes.

Vinegar is often adulterated by fraudulent persons with one or other of the mineral acids. Although the presence of these acids is readily recognisable in distilled vinegar, it is much more difficult in common vinegar, which, containing vegetable matter in a state of intimate combination, will present appearances, when tests are applied, that would be very apt to mislead persons who are not practical chemists. It would, therefore, be of little use to describe the method of detection to any but chemists, and to those it would be superfluous.

Vinegar will keep long in proportion as it has been manufactured well. The objects to be accomplished by the exertion of the manufacturer's skill are the production of as much alcohol from the saccharine substance made use of as can be obtained, and the total conversion, if possible, of the alcohol into vinegar. The perfection of the process is to eliminate all the vegetable matter

which is not converted into acetic acid as much as possible: if this be effectually performed, the vinegar will keep many years, and it will even be continually improving. If much vegetable matter be contained in the vinegar when it is sent out of the manufactory, and especially if in small volume, a singular kind of coagulum is formed, resembling a skin often an inch thick, and having a gelatinous feel with considerable consistence. This is called *mother of vinegar*. When formed it should be separated, for this removes one source of spoiling. Notwithstanding the great bulk of this coagulum, there is really very little solid matter in it. I once dried a sheet of it, and thus obtained a skin nearly as fine as gold-beater's leaf: it was transparent, of a brown colour, and was exceedingly light.

Section II.

VINEGAR OBTAINED BY THE DESTRUCTIVE DISTILLATION OF WOOD.

If a piece of green wood be introduced into an iron retort or other close vessel, the retort bedded in a common coal fire, and a receiver applied, it will be found that in proportion as the wood heats, the water which constitutes its natural juices will distil over, and drop into the receiver. This water almost immediately changes its nature, and becomes first acerb, and then sour to the taste: it comes over impregnated with a dark oil, which soon puts on the appearance of thin tar, and, in fact, is such; part of the tar floats, part dissolves in the liquor; but the greater part sinks to the bottom of the liquor. Meanwhile gas, consisting of carbonic oxide, carbonic acid, carbureted hydrogen, and bicarbureted hydrogen, is generated abundantly. At length the liquor which comes over is very acid; but its acidity is in some measure disguised by the strong taste of the tar, which is dissolved in the liquor, and gives it a reddish colour.

It is easy to trace the theory of these changes. The wood chiefly consists of oxygen, hydrogen, and carbon,

in certain proportions, and in a certain state of combination. The elements separate during the heating of the wood, and they recombine immediately after in different proportions, and give rise to new substances. Part of the oxygen and hydrogen combine and form water. Another part of the oxygen and hydrogen combine each with a portion of carbon, and form two sets of compounds, carbonic oxide and carbonic acid, with carbureted and bicarbureted hydrogen. Another portion of the carbon and oxygen, with a very small quantity of hydrogen, then combine, and produce acetic acid. The remainder of the carbon and hydrogen, with a very small portion of oxygen, also unite and produce the peculiar tar. The water, acetic acid, and the tar, all distil over together, in the form of what is called in commerce *pyroligneous acid.* The acid which comes over towards the end of the distillation is the strongest portion; no doubt because the water which the timber contained has been at this time all volatilised.

The name given to this liquor by the French chemists was pyroligneous acid; but it was announced by Fourcroy and Vauquelin that it is not an acid *sui generis,* or of a peculiar nature, as had for some years before been supposed. They determined it to be merely acetic acid disguised by tar. But this was by no means a new discovery. Glauber had ascertained the same thing two centuries before; for in describing the carbonisation of wood, he notices this acid liquor, and calls it vinegar. The fact seems not to have been generally known; for Homberg stated something similar to the French Academy in 1701 *; and Boyle details some experiments on a spirit drawn from box-wood, in which he at length detected an acid which "was in scent strong of vinegar, so that had I not known how it was obtained I should have suspected it to be *acetum radicatum.*" †

Vinegar, whether obtained by fermentation or by the distillation of wood, is a dilute acetic acid, that is, a mixture of a very concentrated, pungent, and inflammable

* Mémoires de l'Acad. 1701, p. 288. † Works by Shaw, iii. 386.

acid called the acetic, with water in variable proportion. The water may be separated by a variety of means. Thus, if common vinegar be strongly frozen, and the vessel inverted, an unfrozen portion, in small quantity, will run out, which is acetic acid deprived of much water. If this be mixed with charcoal powder and distilled, a liquor will come over (the first portions of which should be rejected), which at a moderate degree of cold will shoot into beautiful crystals.* These are acetic acid, otherwise called *radical vinegar.*

Acetic acid, when as free from water as it can be made, is a colourless liquid at ordinary temperatures, but crystallises in the cold: it has an exceedingly pungent smell, and a powerfully acid taste, amounting to actual causticity. When applied to the skin it is capable of forming a blister, and even a troublesome eschar: it also destroys warts and other excrescences. When heated so as to emit vapour, the vapour will readily catch flame from any burning body. The liquid sold under the name of *aromatic vinegar* is acetic acid, holding camphor and some essential oils dissolved. This compound was formerly known under the name of *vinegar of the four thieves,* or *thieves' vinegar,* on account of the following circumstance:—"When the plague raged at Marseilles, four rogues broke into the houses of the sick, and carried off whatever they pleased, retiring to a secret place with their booty; and they returned to the same business at different times, until they amassed great riches: but they were at last apprehended and hanged. Being asked how they durst venture into the pestilential houses, they said that they preserved themselves by drinking a glass of their vinegar two or three times a day, sprinkling their handkerchiefs and clothes with the same, and they were not afraid." † The vinegar thus perfumed and used by the thieves was, of course, common vinegar, not acetic acid; and all that they contributed to the invention was the idea of combining the

* Lowitz, Crell's Journal, i 241.
† Phil. Trans. abridged by Hutton, &c.

fumes of vinegar with the perfume of aromatics, and using the compound as an alexipharmack, the powers of which are very questionable.

In pyroligneous acid manufactories it is usual to prepare what are called *red liquor* and *iron liquor* for the use of calico-printers. The former is an acetate of alumina formed by mixing the acetate of lime, hereafter to be described, with common alum. By double decomposition, acetate of alumina is formed, which remains in solution; and sulphate of lime, which, being insoluble, subsides to the bottom. This sulphate of lime is not allowed to go to waste: it is employed as the lute with which the end pieces of the retorts are cemented in, and it answers the purpose extremely well. The iron liquor is made by dissolving old iron hoops, &c. in the pyroligneous acid which has been rectified by distillation, but no further purified. In some pyroligneous acid manufactories the acid does not go through all the processes for purification that will be presently described. After being distilled from the iron retorts, the acid is rectified by a second distillation through a common still and worm: by these means a purer acid is procured; but it is far from being as pure as it is possible to obtain it. The steps by which it may be rendered almost perfectly pure are next to be described.

The apparatus and process employed for distilling pyroligneous acid are as follow: —The wood made use of for distillation is introduced into a cast-iron vessel, shaped like a long drum, but of a very large size. This vessel consists of a cylindrical body, generally about six feet and a half long, and four feet in diameter, having two circular end-pieces, which fit in at each end of the cylinder, and are secured there both by moveable bolts and luting. The cylinder is laid horizontally in a fire-place, the fire surrounding it along its whole length. The ends of the cylinder project a little beyond the fire-place, so that they, along with the two circular end-pieces, are always comparatively cool. From the centre of the end-piece of the cylinder springs a very wide tube intended to carry

off the products of the ignited wood, namely, the vapours of the acetic acid, the tar, the water, &c. This tube at length traverses a large cistern of water kept constantly cold, and ends in a copper worm surrounded by a refrigeratory: the water, acetic acid, and tar, are condensed in it; they are discharged in a state of mixture into a large cistern: here the liquor is allowed to separate: the great bulk of the tar subsides to the bottom. Above this lies the acetic acid and water mixed, and holding in solution as much tar as imparts a considerable degree of taste and smell. Floating on the surface of all lies a little more tar of less consistence and less specific gravity than that which has sunk to the bottom. In order to separate the acid liquor, which constitutes the middle stratum, a pump is made use of, the lower end of which plunges so far down into the acid liquor as to be but a few inches from the lower deposit of tar. When the pump is put in action it draws the acid liquor out, and at length the upper tarry surface is depressed until it joins the lower deposit of tar, when the pumping is discontinued. This is the first step towards removing the tar; and by it the chief quantity is removed. The acid liquor removed by the pump is received into the body of a large still, where it undergoes the process of distillation. This distillation is conducted slowly: the object of it is to remove another portion of the tar which is held in solution by the liquid; and if the distillation were urged by a strong heat, the separation would be much less effectual. The first product that distils over is of a peculiar nature: it is called *wood spirit*, and is kept separate, for a purpose that will be presently mentioned. The product which follows this is still a tarry vinegar; for it now holds in solution not tar but the essential oil of tar: it has still the strong taste, but by no means so strong as when first obtained from the wood. When nearly the whole of the acid has been drawn off the process is stopped; and the tar now collected in the bottom of the still is allowed to run off by a cock.

The tarry vinegar produced by this distillation is no

longer red; it is now quite pale, and is even a little milky. It can never be rendered much purer by repetitions of the process; for such is the affinity of the tar-oil to the vinegar, that they will both rise in the still, and come over together. The method of separation adopted is engaging the vinegar, which is the solvent of the tar-oil, by means of its affinity to an alkaline substance. The liquor is accordingly saturated either with lime or carbonate of lime. The latter succeeds better, as it exerts no action on the tar-oil, which therefore, to a certain extent, separates, floats, and may be readily removed by skimming. The objection to carbonate of lime is the expense. When lime is used, it not only saturates the acid, but it combines in some degree with the tar-oil, and forms a saponaceous compound: another portion of tar-oil separates, and floats; as in the former case. The solution of acetate of lime, by saturation still further purified, and decanted off clear from any excess of lime and a little tar-oil which falls, is evaporated to dryness in an iron boiler. During the evaporation to dryness, especially towards the latter end, when the boiling process is somewhat elevated above 212°, some tarry matter is volatilised. The acetate of lime which results from this process is almost white: it is in small dry masses. This salt is introduced into a cast iron still with an earthen head. The beak of the head enters a large cask containing pure water: sulphuric acid is poured into the iron body, over the acetate of lime, and heat is applied. Vapours now arise, which are concentrated acetic acid, and which contain almost no impregnation of tar. These vapours pass over through the beak into the cask of water where they are absorbed: the water becomes more and more acid; and at length, when sufficiently impregnated, which is known by its increase of specific gravity, the *wood vinegar* is finished.

When well prepared, it has scarcely any peculiar smell or taste: it contains no foreign vegetable matter, and is therefore purer than that from malt, sugar, fruit, or wine. It succeeds better as a pickling vinegar, be-

cause it may be concentrated to any strength. It is perfectly transparent and colourless.

The best timber for making pyroligneous vinegar is oak: but beech, ash, sycamore, and birch, answer exceedingly well; in short, every kind readily procurable is found to succeed, except elm, and the different kinds of fir. A singular circumstance is asserted by the manufacturers, namely, that elm timber, on distillation, does not afford acetic acid, but a watery liquor. Probably it affords a little acid, but so little as to be inappreciable. Dry timber affords a less abundant, but more valuable product. It should never be used in log, but cleft, as otherwise there would be much waste of fuel in permeating the large masses of wood by the heat.

Taking the average of the different kinds of timber, it may be stated, that the quantity by measure of tar obtained is about one twelfth of the product of the whole distilled liquor. The ratio of pyroligneous acid can scarcely be determined, it depends so much on the mode of applying the heat, the age of the timber, and various other circumstances.

Generally speaking, a gallon of the liquor, as distilled from the average charge of the retorts, affords when saturated with lime and evaporated to dryness about one pound of acetate of lime. And a pound of acetate of lime, when put through the process of decomposition by sulphuric acid, as already described, is capable of affording five pints of good house vinegar.

Instead of the apparatus just described, namely, the cylindrical retort, some manufacturers make use of the ordinary still, head, and worm; the two former parts of the apparatus being made of cast metal, and the latter of copper. Various modifications of the apparatus have been also introduced. Formerly, the inflammable gases generated during the distillation of the wood were allowed to escape into the air; at present, they are conveyed, by means of a tube springing from the retort, into the furnace where the fire is burning, and thus contribute to heat the retort, and cause a considerable sav-

ing of fuel. In burning, the gas produces a flame possessed of sufficient illuminating power to render it an object of some consequence in this respect. The inflammable gas comes over chiefly during the last three or four hours of the distillation. Its illuminating power is at first very feeble; it then increases; is at its maximum towards the end: it then suddenly diminishes; in a short time it does not exceed that of hydrogen; immediately after, the flame goes out.

There is another process for purifying pyroligneous vinegar which has been also employed, and presents a very pure acetic acid: it is thus described by Thenard:—As much chalk is added to the impure acid as can be decomposed by it at the ordinary temperature; a blackish-brown froth is formed, which is carefully removed. The liquor is then made to boil, and the saturation is finished with lime. A proper quantity of sulphate of soda is then added, which produces acetate of soda, and sulphate of lime, the latter of which being insoluble precipitates, and draws down along with it more or less tar.

When the sulphate of lime has subsided, the solution of acetate of soda is decanted off, and is evaporated to a pellicle: on cooling, it concretes into a crystalline mass. This is very impure: it is black; and is greatly impregnated with tar. It is purified by causing it to undergo the igneous fusion, re-dissolving it in water, and crystallising it at least once: during the fusion, the tar is either volatilised or carbonised, and the crystals formed are perceptibly purified. The crystals thus obtained are dissolved in water, and sulphuric acid is added: sulphate of soda is produced, which crystallises almost entirely; and the mother liquor, being distilled, affords pure acetic acid. The specific gravity of the acid prepared at Choisy is 1·057: it is capable of saturating about three tenths of its weight of subcarbonate of soda.*

The following method of purifying pyroligneous acid has been given by Berzelius: he says that it may be

* Thenard, Traité de Chimie, iii. 62.

deprived of even the last traces of empyreumatic oil by means of animal charcoal. He found that the carbonaceous residuum left in the making of Prussian blue, when the prussiate of potash has been extracted, posseses this property to such a degree, and so effectually removes the empyreumatic taste, that the smallest quantities are sufficient; and that it is only necessary to mix the acid with the charcoal, and filter forthwith. He proved, also, that the acid thus deprived does not recover its empyreuma; for some that had been loosely corked in a bottle was after five months as good as ever.*

Lowitz long ago showed the purifying power of common charcoal on pyroligneous acid. He says, "The so called acid of wood, which I obtained by distillation from lignum vitæ or guaiacum, was like vinegar very readily purified by distillation with charcoal, from the great quantity of empyreumatic oil which adheres to it. It thereby acquires the taste and smell of distilled vinegar; and after concentrating it to a very high degree by one of my new methods (freezing) I have brought this acid of wood, as it is termed, to crystallise in the same manner as vinegar, and have thus obtained a true glacial vinegar."†

It has been ascertained that pyroligneous acid in its unpurified state possesses the remarkable and useful property of preventing the putrefaction of animal substances, and even of checking putrefaction when begun. It has been always known that smoked provisions keep better than those which have been dried, an effect which seems to depend on the impregnation of pyroligneous acid, which they receive from the smoke; for it is turf smoke that is employed, and turf by distillation in close vessels affords pyroligneous acid. The following account is given by Mr. Ramsay of experiments made by him: — A number of herrings were cleaned on the 10th of July, 1819, and, without being salted, were immersed for three hours in distilled pyroligneous acid (sp. gr. 1012). When withdrawn, they were softened, and not so firm as when first taken out of the common pickle. They were hung

* Bulletin Universel, E. vi. 6. † Lowitz, Crell's Journal, ii. 250.

up in the shade. July and August were very hot months; but the herrings had no sign of putrefaction about them, but had a very wholesome smell combined with that of the acid. One of them being broiled, the empyreumatic smell was very strong. The rest, in six months, were in complete preservation.

It was afterwards found that the period of immersion had been too long. If the fish be simply dipped in acid of specific gravity 1012, and dried in the shade, it is sufficient for their preservation; and such herrings when broiled are very agreeable, and have not the disagreeable empyreuma of the former.

A number of haddocks were cleaned, split, and slightly sprinkled with salt for six hours: then being drained, they were dipped for about three seconds in pyroligneous acid, and hung in the shade for eight days. On being broiled, they were of an uncommonly fine flavour, delicately white, and equal to the highly esteemed *Finnan* haddock. Herrings were cured in the same way as the haddocks. After being dried in the shade for two months, they were equal in quality and flavour to the best red herrings. The fish retained the shining and fresh appearance which they had when taken from the sea.

A piece of beef was dipped for one minute in pyroligneous acid (sp. gr. 1012) in July, 1819. On March 4th, 1820, it was as free from taint as when first immersed. No salt was used in this experiment. A piece of beef was dipped at the same time in pure vinegar of specific gravity 1009. It was perfectly free from taint on the 18th of November. This experiment indicates antiseptic powers in pure vinegar: some haddocks were cured with it which remained free from taint, and when cooked had an insipid taste.*

Dr. Jorg of Leipsig repeated some of these experiments, and with success. He even succeeded perfectly in making anatomical preparations by application of pyroligneous acid. †

* Edinb. Phil. Journal, iii. 21. † Philosoph. Magazine, liv. 69.

It has been already stated, that in the second distillation of the pyroligneous acid, the first product that comes over is of a peculiar nature, and is called *wood-spirit.* This is purified by several distillations from some alkaline substance, as lime, or from oxide of lead; and when sufficiently rectified it assumes the appearance of a transparent and nearly colourless fluid, possessing many of the properties of alcohol. At first it was considered identical with alcohol; but there are points of difference. It is highly inflammable; and burns with a pale flame, emitting very little light. It has a peculiar penetrating smell, and a strong somewhat ethereal taste. It dissolves Indian rubber, and forms a varnish applicable to a variety of purposes. This solution of Indian rubber is also used in the manufacture of a useful and beautiful water-proof woollen cloth. Wood-spirit dissolves resins; and hence is used by some makers of water-proof hats, as a less expensive solvent of the resins used in their process than alcohol, and equally effective.

This wood-spirit is called by chemists *pyroxilic spirit.* When rectified from muriate of lime, it is of specific gravity ·828. It boils at 150°. It burns away without leaving any residuum.

CHAP. X.

BAKING.

The word *baking,* in the common acceptation of it, signifies a particular process in the art of bread-making. From the etymology of the verb *to bake,* we learn that in strictness it means to dry any thing by heat; and it is in this sense that it is still generally understood. It means the application of a scorching heat to dough after it has undergone fermentation. There is no good reason, however, for a fastidious adherence to this limited sense, when a more extended application of the term is so much

more convenient. The title of this chapter, therefore, is to be understood to comprise the whole process of making bread, from the wetting of the flour to the removal of the loaves out of the oven.

The different nutritious grains so much resemble each other in composition and properties, that they may be properly comprised under the description of one, and that one shall be *wheat*. This will introduce all the proximate principles which it is necessary to understand for acquiring clear views of the nature of the process under consideration.

Wheaten flour consists of two principal ingredients,—one called *starch*, *farina*, or *fecula*, which is the more abundant of the two; and the other *gluten*, which is the more nutritive. According to Vogel's analysis, wheat-flour, in one hundred parts, contains starch 68, gluten 24, gummy sugar 5, and vegetable albumen 1·5. But Sir H. Davy has shown that the proportions vary with the goodness of the wheat, and he has obtained higher averages. Barley contains much less gluten. The nutritiveness of grain is in proportion to the quantity of gluten which it contains: hence wheaten bread is the most nutritive of all bread, because it contains the greatest quantity of that principle.

The analysis, or separation of these two proximate principles, starch and gluten, may be effected by a very simple process. Let a little good wheat-flour be made into a paste with a little water; let the paste be worked up in one's closed hand under water; and let the water be frequently changed as long as it continues to be whitened by the flour. The portion which remains in the hand will now be found very different from the original flour. It is a tasteless, fibrous, tenacious, tough, elastic, grey mass, stretching, when drawn out, to a great extent, and collapsing again like Indian rubber. It dries into a brown, hard, semi-transparent mass, which is brittle, breaks with a glassy fracture, and if suddenly heated melts and burns with the smell of horn. The name gluten is derived from its glutinous

quality; and this it possesses to such an extent that it acts as a cement for broken glass and porcelain. It is scarcely, if at all, soluble in water; but it dissolves readily in acids, and may be precipitated again by alkalies, but in an altered form. It is asserted by Taddei that gluten, and flour as containing it, possesses the important property of acting as an antidote to the poison of corrosive sublimate.

Gluten long resists putrefaction, but when kept moist for a length of time it putrefies; carbonic acid, and probably acetic acid, are generated along with ammonia: a substance closely resembling cheese is the result, and this eventually changes to a matter possessing some of the properties of a resin.

Although gluten is a substance chiefly of a vegetable nature, it partakes also of an animal constitution. It contains azote; in putrefying it exhales the odour of putrescent animal matter: a fatty matter has even been discovered in it after it has undergone putrefaction; and ammonia has been obtained from it by distillation. It burns, as already mentioned, with a smell like that of horn; and, like flesh, it is converted into a fatty matter by nitric acid. All these are proofs of an animal nature. Its origin, and the circumstance of its containing woody fibre, as has been sufficiently proved by chemists, are proofs of its vegetable nature.

But gluten, although generally considered a proximate principle of vegetables, is not strictly such; as it is not of the same nature throughout its whole composition. It has been ascertained to consist of two distinct substances, which may be separated by a simple process. Let gluten be well worked between the fingers, as already described, not in water, but in a large quantity of alcohol. A part dissolves in the alcohol, and may be obtained from the solution by evaporation at a low heat. This constituent of gluten has been called *gliadin*, from γλια, glue. The part which refused to dissolve in the alcohol is called *zimomin*, from ξυμη. (Xumè) leaven. Of these two substances is gluten composed; they are, therefore, the real proximate principles.

Gliadin is a somewhat transparent, yellowish, brittle substance, emitting the smell of boiled apples when heated, and having a sweetish taste. It does not dissolve in water: it requires a large quantity of alcohol to dissolve it, unless boiling. It burns like animal matter. Zimomin is of a dirty white colour, hard, and without any of the elasticity which gluten possesses. By being soaked in water it is rendered soft and partly adhesive. It burns like animal matter. Its most remarkable property is that of forming a blue colour, when mixed with powdered resin of guaiacum, and as much water as will form them into a paste. This resin may therefore be usefully applied as a test of the presence of zimomin in flour, thus distinguishing such flour as has lost its gluten by spontaneous decomposition. The contact of air is necessary to the change of colour, as is proved by the internal parts of the paste remaining white. The intensity of the blue is an index to the quantity of zimomin contained in the flour, and therefore to its goodness and fitness for making a nutritious wholesome bread.

The water which has been made use of for washing wheat-flour, so as to obtain its gluten, is white, on account of a large quantity of matter which it holds suspended. This white matter will at length subside: it may be collected on a filter and dried: it is then starch or farina. The word farina is thus general: it means the meal of any corn.

The presence of starch may be detected in any substance by iodine, which is the most delicate test of it; but the iodine must be in an uncombined state. The moment that its solution is added to water, in which a little starch is suspended, a fine blue colour is produced.

Starch is contained in a variety of other substances beside the nutritive grains. The starch from potatoes has been already noticed. It may readily be prepared by breaking down raw potatoes with a common grater; mixing the pulp thus obtained with a large quantity of water; straining through a hair sieve; and allowing the strained liquor to subside. After some time a

brilliant powder will be found in the bottom of the vessel, which, when well washed, becomes exceedingly white and granular. This, when dried, is the substance required. By a process nearly similar, the starch called *arrow-root* is obtained from the roots of the *maranta arundinacea,* which resembles potato-starch in almost all respects. Indeed the latter is very often fraudulently substituted for arrow-root, and by inspection it would not be possible to distinguish them. I ascertained many years ago that they may be distinguished in the following manner: — The jelly prepared by boiling arrow-root in water grows more fluid as it cools; while that made from potato-starch becomes more firm. The chief ingredient in the nutritious articles called *salop, tapioca, sago,* and a few others, is a variety of starch different in each. The plant which produces tapioca is known to be poisonous, although that substance is wholesome.

Previously to entering into any details on the various operations of the baker, it will be expedient to describe the processes which the grain is made to undergo, with a view of reducing it into flour.

When the wheat leaves the market, it is not sufficiently dry to permit its being ground: instead of reducing to flour between the mill-stones it would clog in the furrows. The first step is, therefore, to deprive it of this redundant moisture. This is done on a kiln, constructed of a floor of tiles, perforated with a vast number of holes, small at the upper surface, but very large underneath. The floor is heated by the hot air proceeding from a fire which burns below.

Instead of earthen tiles, perforated metal plates are sometimes made use of: their effect is to communicate the heat more rapidly to the grain, on account of the superior facility with which metals conduct heat: but there is a great risk that the external part of each grain will be so hardened by this quick heat, that the moisture within will be actually incarcerated. On this account the earthen tiles are generally preferred.

The grain is spread thick on the kiln in proportion as the area of the latter is small. If the floor of the kiln be eighteen feet square, the grain may be spread five inches thick; or six inches to a square of twelve feet. Each batch of grain should occupy the kiln about three hours and a half; and during that time it should be turned up well from the bottom twice. The heat of the surface of the tiles should be the greatest that one's hand can bear without actual pain. In proportion as the grain heats a steam rises from it, and this ascending along with the heated air is carried off through the louver. As long as the steam appears the corn is not yet dry. When this ceases, the corn is removed from the kiln into a loft or floor, where it is left to cool and mellow. Were it ground immediately on leaving the kiln, the flour would make inferior bread: a paste made of it with water would be gluey and not tough. The paste when made into a ball, and set by for some time, would fall flat instead of retaining its shape, as it should do, were the flour in good condition, and not too young from the kiln. The dried grain is generally left about six days on the cooling loft before it goes to the mill. If it have been rightly dried, a grain chewed between the teeth should not snap short, but gradually give way with some degree of toughness. If it snap short it has been over-dried, and such will afford an ill-coloured flour.

The next step is to cleanse the grain; and this is effected by various processes. After leaving the cooling floor the grain is let into the *separator*. This is a cylinder composed of wire hoops, placed so near each other that all the grain will be retained within, except that which is very small, and which, by affording proportionately more bran than flour, would not be worth grinding. This small grain is sold to the distiller. The separator is, in fact, a screen of a cylindrical form, placed horizontally, turning briskly on its axis, and shaking out any small grain, sand, or other foreign matter which may be small enough to pass out between the wires of

which the instrument is composed; the stones and large pieces of foreign matter being thrown out at its end. The wire is what is called No. 13.; and there are fourteen hoops of it to every inch of cylinder.

From the separator the grain is let into the *screen*, properly so called. The object of this machine is to cut off the fine fleecy down which is found at the *rough end* of the grain, as it is named by millers. The screen is a cylinder of sheet iron, placed horizontally, and turning quickly on its axis. It is punched full of holes from the outside, the *burr*, of course, pointing towards the axis. It is, in fact, a large grater, the burr being reversed. Inside of this sheet-iron cylinder is another similarly punched with holes, but from the inside outwards. Between the inside and the outside cylinders there is on every side a space of about five eighths of an inch, and in this space lies the corn. The action of the burrs, during the rotation of the cylinder, is to grate or rasp off the rough end of the grain. The matter thus removed falls out of the cylinder through the punched holes, and is separated altogether from the corn. It is a brown-coloured, soft, short, flossy kind of hair or down, a little resembling cowitch in appearance.

The next part of the cleansing process is performed with the *joggling-screen and fans*. The joggling-screen is a long trunk made of boards, except the bottom, which is of wire-gauze, — eight wires of warp and the same of weft to the square inch. This trunk takes a motion from the moving power of the mill, by which it is quickly shoved backward and forward, like a sieve in sifting a powder, which in fact it is. At the same time the fans excite a current of air through the agitated grain which blows off any adherent dust, along with any bran abraded by the screen. The fan is composed of two boards which cross each in the middle at right angles, thus forming four fans. The axis on which they turn is parallel to the plane of the boards. In turning, the four fans excite the necessary current of air.

The corn, now thoroughly cleansed, is next let into the *hopper* or funnel, through which it is slowly passed between the two mill-stones, where it is ground. Every one knows the manner in which these stones act. By the attrition the corn is broken down into powder, and with such force, that the *meal*, as the ground corn is called, comes out of the stones quite warm. The stones should be set and chiselled in such a way, that the grain may be rather broken down than cut: were it cut, the bran, instead of being merely detached, which is the real object, would be reduced to a powder along with the farinaceous part of the grain, and would eventually find its way into the flour. By a simple contrivance, the stones can be set nearer or farther from each other, so as to grind coarse or fine.

The meal, that is, the mixture of flour and bran, is then transferred to a new screen, the object of which is to separate the former from the latter. It is quite obvious that a common sieve would effect this purpose, although not conveniently or expeditiously. Instead, therefore, of a common sieve, a cylinder is made use of, composed of wire-gauze. This cylinder is not moveable: it is not placed horizontally, but is raised at one end, so that it forms an angle of about 40° with the horizon. Within this cylinder, and in its axis, is a swivel or rod, extending throughout; to this are fixed hair-brushes, which touch the wire-gauze cylinder. When the swivel turns round, which it is made to do briskly by the moving machinery, it brushes the whole length of the wire-gauze cylinder; and when the meal is introduced, the flour is actually forced through the minute meshes of the gauze, and is thus prevented from clogging them up, as would happen but for the brushes. The wire-gauze is not of the same degree of fineness throughout the whole length of the cylinder, but becomes finer as it dips downwards. Thus the flour, which passes through the wire-gauze, is of different degrees of fineness. What remains in the cylinder is again ground between the stones, is passed through the wire-gauze cylinder, and

affords a flour of an inferior quality. The portion which the cylinder detains is ground a third time, is passed through the cylinder, and furnishes a flour of a still inferior quality. What remains now is *bran*.

It need scarcely be observed, that the better the flour the better will be the bread: French bread is made from the very best or *firsts*. To obtain flour of this kind, the wheat must have been of the best quality, and the flour must be obtained from the first grinding only. The best wheaten bread is made from *firsts* flour only; ordinary bread from *firsts* and *seconds* mixed; but *thirds*, or the produce of the third grinding, ought to be excluded, but is not always. Brown bread is made from a mixture of firsts, seconds, and *whole meal*, as the produce of the first grinding is called just as it leaves the mill-stones, and without having any flour separated from it. Brown bread, as containing bran, which is known to contain a resinous purgative matter, is of an aperient quality, and is consequently often preferred by valetudinarians; but it is generally made too fine to be of any efficacy.

The yest employed by bakers is made expressly for their use. Ale-brewers' yest succeeds admirably; but it would be difficult to procure it in sufficient quantity. As it comes from the porter-brewer it is too much impregnated with the bitter principle of the hop; it, therefore, requires to be washed with cold water, so as to remove the chief portion of the bitterness. The washing has also the effect of removing a portion of the colouring matter of the yest; for, without this precaution, bread made from it would be highly tinged: even washed yest renders bread in some degree foxy. Distillers' yest, as having neither bitterness nor colour, succeeds well; but it is scarce.

The yest used in extensive bakeries is made in the following manner: it is altogether a distinct branch of trade. The process resembles that of the brewer in most respects. A quantity of malt properly ground, suppose a barrel, is mashed with warm and hot water,

applied in successive quantities, in such proportion as to afford about four or four and a half barrels of wort. This is boiled with seven pounds of hops, and is let down on a cooler. When cooled to about 65° in winter, or to the natural temperature of the air in summer, two stones of flour of first quality are mixed, first with a small quantity of the wort, so as to be intimately blended, and afterwards with all that remains. A quantity of brewers' best yest is then well mixed in. Fermentation ensues: a high head of froth rises; this soon arrives at its maximum; when it begins to decline, the whole is strained through a sieve, and is fit for use.

Salt is used in the making of bread, partly for the sake of flavour. It stiffens the clammy soft dough made from new flour, and gives it a fair colour, when otherwise it would be foxy. Its quantity must vary with the quality of the flour: bad flour will bear less salt than good. With good flour, the quantity for four hundred-weight is seven pounds. Old flour requires little salt; new flour requires twice as much as old. Salt possesses the very important property of causing the dough to rise better.

Flour, by being converted into bread, is increased in weight by 0·241; that is, one hundred-weight of flour produces 139 avoirdupois pounds of bread. In this estimate it is supposed that the bread has been thirty-six hours out of the oven. But if the bread be weighed immediately on leaving the oven, it will weigh 144 pounds. If the flour be of a very superior quality, the bread on leaving the oven may even weigh 150 pounds. This precisely agrees with the estimate of Pliny, that the bread should weigh one third more than the flour which produced it. The proportion of bread to the original flour is, however, variable according to the nature of the season in which the wheat grew, and according to the age of the flour. The better and older the flour the more water it absorbs to make dough, and the more it retains of it in baking. The best flour absorbs about

three fourths of its weight of water, and the worst only one half.

The following is the process for making ordinary wheaten bread:—About five imperial gallons of artificial yest, such as has been already described, are mixed with as much hot water as will bring the whole to a degree about blood heat. This liquor, with three pounds and a half of salt dissolved in it, is thrown into a wooden trough. The total quantity of flour to be used is four hundred-weight; but only about a third of this quantity is mixed with the liquor in the trough at first. The mixture is then well worked up with the hands until it is perfectly uniform throughout, and is quite free from lumps: this is called *sponge*. Its surface is then made flat and level; a little flour is sprinkled on, and the whole is covered up closely. In this state it is left for about twelve hours, if artificial yest had been used; but for half that time, if washed brewers' yest was employed. During this period a fermentation takes place; the bulk is greatly increased, owing to the involution of a vast number of air bubbles. The sponge is then diffused through a quantity of water, cold in summer, and scarcely warm in winter, holding three pounds and a half of salt in solution. All the rest of the flour is then to be added, and the whole is to be well worked up into an uniform stiff paste: this is called *dough*. When the dough is made it is covered up, and is allowed to rest an hour and a half. It again swells, and when sufficiently spongy, it is called *proof*, and is fit for weighing into masses or loaves. The loaves are then introduced into the oven.

The oven is a kind of arched building, with a floor perfectly flat and level: the floor is laid with tiles; but they should not be fire-tiles, as these are particularly apt to scorch the bread: the arch is built of brick. At one side of the oven is a kind of furnace provided with an iron door in front. The furnace has a very short flue, perhaps not more than a yard in length, which turns abruptly into the oven. The hot air from the furnace, therefore, enters the oven; and having traversed it,

passes out of it in front, and ascends into a vertical funnel built over the mouth of the oven. When a batch of bread is to be baked, a fire is kindled in the furnace, and a quantity of coal laid on: the oven then begins to heat; but the bread is not put in until the bitumen of the coal is burned off, or, in other words, until the coal is burned to cinders, and has ceased to smoke. When this has happened, the oven is ready to receive the bread. The smoke and soot are not suffered to lodge in the oven, but are carried up the funnel over the mouth of the oven, the ascent being promoted by laying a blaster over the mouth: the blaster is a large piece of sheet-iron.

The floor of the oven is then covered with loaves laid on one by one, and beginning with those of the large size, so as to allow them more time to bake than the small ones: they are all placed side by side, but never one over another. The floor of a good-sized oven is eleven feet by nine: if all the loaves were such as to weigh four pounds five ounces and a half, that is the quartern size, the floor of the oven would conveniently hold 140 or 150 such. When all the loaves are in, the door of the oven is shut, and the heat is kept up for two hours, at the end of which time, provided that the heat has been rightly managed, the bread has been sufficiently baked, and has lost one tenth of what it weighed when put into the oven. It is then taken out of the oven, and is left to cool, during which a further evaporation takes place, and consequent loss of weight, as already described. In small loaves the loss of weight in the oven is in a slight degree greater.

As all the loaves contained in the oven are lying in contact, it is plain that the sides of each loaf are protected from the heat, and are therefore not scorched. The under surface rests on the tile floor, which being a bad conductor of heat, scorches it very little; but the upper surfaces of the loaves being all exposed to the direct influence of the hot air, issuing in from the furnace, are considerably scorched. This is the cause of the difference in the appearance of the two crusts. The

oven is known to be properly heated to receive the bread, when a little flour thrown in on its floor blackens without taking fire. But every kind of flour will not answer for this trial. Old flour would lead us into an error; it will take fire although the floor will scarcely blacken new flour. The newest flour is the best for the purpose. The temperature, as stated by Tillet, is 480°.

The kind of coal which answers best for heating the oven is that which is called *swift* in burning. Scotch coal is therefore excellent. When Troon coal can be procured, it is to be always preferred.

It is well known that potatoes are often used by bakers in making bread, and a great popular clamour has been raised against the practice. It is to be observed, however, that when the use of them is confined within moderate limits, there is neither fraud nor injury to the public. The following is the manner of using them.

A cask is to be prepared by boring holes in its bottom: and the bottom is made to fit into the mouth of a boiler containing water. If the quantity of flour to be baked be four cwt., the quantity of potatoes that can properly be used is five stone. The potatoes are thrown into the cask, a cover is applied, the water is made to boil, and the steam ascending through the holes in the cask boils the potatoes. The boiling is continued until the potatoes crack and become mealy. They are then withdrawn, and are pounded with a wooden instrument until they become quite fine. While this potato-meal is still very hot, cold water is added, in such quantity as to reduce the whole to the thinness of buttermilk. To this liquid, still warm, a gallon of yest is to be added. A fermentation commences; and after it has continued sufficiently long, during which the potato-meal rises to the top and forms a tough mass, the whole is to be well mixed; and being now a homogeneous liquid, it is to be strained, first through a coarse hair sieve, and afterwards through a finer.

To this strained matter, one half of the whole quantity of flour is to be added, and well worked up with the hands so as to form sponge. When the sponge has duly fermented, the other half of the flour is to be added along with some more water holding salt dissolved ; this mixture is to be worked up into dough, and treated in the usual manner.

This bread, when rightly managed, is not distinguishable by the nicest judges from that which has been made from flour only. It will keep for a week or ten days without a trace of sourness. The specific gravity of the bread seems to be a little diminished by the potatoes; for the loaf is a little more plump than the same weight of bread made from mere flour: the bread even looks better. It is surprising how little the five stone of potatoes contributes to increase the weight. The quantity of bread, which the four cwt. of flour by itself would have afforded is increased only, on an average, about half a stone, by the addition of the potatoes. It appears, therefore, that the employment of potatoes, in the above-mentioned quantity, is not done for any fraudulent purpose, but to improve the quality of the bread: the small advantage by the increase of weight is perhaps more than counterbalanced by the additional trouble which the use of potatoes occasions.

It is certain, however, that there are bakers who use potatoes with another intention than that of improvement: as well as in much larger quantity than has been above specified. Bread of this kind is remarkable for its tendency to crack and crumble, and for a dark-coloured streak, sometimes a little transparent, which runs along the margin of the under-crust, almost the same as forms when malted flour has been employed. When such bread, if stale, is cut even with a sharp knife, it will stick to the knife, and appear clammy.

Yest is not indispensable in the making of bread : a very light quality may be made without it, and this method is practised in many countries, and has been from the earliest records of time. If flour be mixed

with a sufficiency of water, and worked up so as to form dough: and if this be set by in a warm place, it will undergo a spontaneous fermentation: it fills with bubbles of air, becomes spongy, light, and swells up. It also becomes sourish, and if allowed to proceed through the natural course of changes, it would run into putrescency. When the dough has become spongy and acid, it is called *leaven*, and in this state is capable of acting as a ferment on new dough. Leaven will be always the better if it be continually propagated from former leaven: that is, if new dough be left to become spongy and sour, this stage will be produced with more difficulty, and with greater tendency to putrescency, than if the dough had been originally mixed with some leaven of a former process. The period generally required for the due fermentation of leaven is about a fortnight: it should not have acquired its greatest sourness. But the time depends on the temperature at which the leaven has been kept: at 80° it will be fit for use in much less time than a fortnight.

In order to make leaven-bread, a quantity of good wheaten flour, and, if procurable, about one fifth of rye flour, is to be made into dough with water at blood-heat. A very small bit of leaven, in the state already described, is to be intimately mixed with it, and the mass left in a warm place, covered up. In a few hours, the dough will have become swollen with involved bubbles of carbonic acid, and as soon as it is puffed up to as great a volume as it will readily swell to, it is to be mixed with an equal bulk of newly-made dough, in which the necessary quantity of salt is contained. The whole is then to be exceedingly well kneaded; allowed to remain two or three hours, during which the mass will again swell, and being made into loaves, it is fit for the oven. The time necessary for baking is the same as for yest-bread.

The very light, spongy, and superior article called French bread is made in the following manner:— If a peck of the very finest quality of wheaten flour is to be

made into French rolls, a small quantity of it is to be mixed with as much warm water as will convert it into dough: in the water a handful of salt should have been previously dissolved. About a pint of distillers' yest, or if this cannot be obtained, ale-brewers' yest, which has been washed with some cold water to remove the bitterness, is to be well worked into the dough. This is to be set by in a warm place to ferment. Meanwhile all the rest of the flour is to be mixed with as much warm milk as will form a sponge. Half a pound of butter melted at the lowest possible degree of heat is to be poured on, along with six eggs; and the whole is to be hastily mixed up together, along with the sponge, provided that it has sufficiently fermented, and is sufficiently swollen. After the mixture, let the dough be left in a warm place, and when it has risen sufficiently, let it be divided, shaped into rolls, and baked in a moderately heated oven. The oven should, as in all other cases, have been perfectly heated before the bread is put in; and the heat should be equal throughout, however difficult this may be to effect with some ill-constructed ovens.

Biscuit-bread is made in the following manner: — The necessary quantity of flour is to be mixed with water in such quantity that the dough produced will be the stiffest and most solid that it will be possible to work. So hard ought this dough to be that it would not be possible to knead it with the hands in the usual manner. Two methods are resorted to. The dough being spread out, a cloth is laid over it, and a man tramples it in all directions with his feet. Or a long bar of wood, having a sharp edge, fastened at one end to a block, yet with sufficient liberty to move with a kind of chopping motion, extends over a table on which lies the dough flatted out. The dough is chopped in all directions, is often doubled up, flatted, and chopped again. When sufficiently kneaded, it is rolled into cylinders of about an inch and half diameter, and these are cut into lengths the same as their diameter. They are then flatted, and moulded with the hand; some

holes are struck through with a *docker*. After a slight sprinkling with flour, they are laid on the tiles of the oven and baked.

Although pure and nutritious bread is so necessary to health and life, there is no article more liable to sophistication. The practice of mixing potatoes with the dough has been already noticed. Potato-starch is used for adulterating flour. Of this I have positive proof, even in the present day. A few months since an eminent flour-factor showed me a powder which he said had been sent him as a substance which might be mixed with flour without discovery, and requested me to examine it, declaring his intention, at the same time, of publishing the transaction. Inspection alone was sufficient to convince me that the powder was potato-starch, and a few experiments soon decided the point. This fraud has no other bad effect than in lessening the quantity of nutritious matter which a given quantity of the bread should contain; beside the extortion of charging full price for an article of less value. Inspection by a high magnifier will detect potato-starch in flour, by its glistening, granular appearance.

We have heard of bones, burned to whiteness, and ground to an impalpable powder, being used to adulterate *thirds* flour, which, being of a somewhat gritty nature, will disguise the grittiness which it is almost impossible to deprive bones of, be they ever so laboriously ground. This fraud is easily detected; for if much dilute muriatic acid, that is, spirit of salt mixed with water, be poured on such flour, there will be an effervescence or boiling up; and if the liquid be thrown on a filter of paper, the portion which runs through the paper will let fall a white heavy deposit, when pearl-ash is added.

Chalk and whiting are also adulterations which, in small quantity, are often mixed with flour, and although such admixtures are not noxious to health directly, they are injurious in many ways. They may be readily detected by pouring on a large quantity of dilute sulphuric

acid, that is, oil of vitriol mixed with six or seven times its weight of water; if an effervescence ensue, it is proof that there is adulteration, and if after filtration, as before directed, the addition of pearl-ash to the clear liquor produce no muddiness, or a very slight degree of it, the presumption is that the adulteration was chalk or whiting.

Alum is a well-known sophistication of bread, not used on account of its quantity, but to disguise a bad quality of flour; it is said to whiten ill-coloured flour, and to harden and whiten bread made from flour which has been malted. By some respectable bakers it has formerly been used, and might still be used, if there were not a law against it, with perfect safety; in so small a quantity as half a pound of alum to one cwt. of flour, it could not be in the least degree injurious; for this would be but nine thirty-fifths of an ounce to the quartern loaf. When used in double this quantity, as it often is, it becomes discoverable to the taste when the bread grows stale. Be this as it may, we can easily detect alum in bread, for it is only in bread that it need be suspected, by pouring boiling water on it, letting it cool, pressing out the water, boiling it away to one third, allowing it to cool, filtering it through paper, and adding to the clear liquor some solution of muriate of lime. If a considerable muddiness now appear, it is proof of adulteration, and none other can well be suspected than alum. Muriate of lime can readily be prepared by pouring a little dilute muriatic acid on more chalk than it can dissolve, and after the effervescence ceases, filtering the liquor through paper. What passes through the filter is ready for use as a test.

Salt, which in small quantity is absolutely necessary to the flavour of bread, is used by fraudulent persons as an adulteration; for a large quantity of it added to dough imparts to it the quality of absorbing, concealing, and retaining a much greater quantity of water than it otherwise would. Bread made from such dough, will, on leaving the oven, come out much heavier than it

ought, and the additional weight will be merely water. Fortunately the taste of such bread is sufficient index to its bad quality; it is rough in its grain, and has this remarkable quality, that two adhering loaves will generally separate unevenly, one taking from the other more than its share.

The following account of a new and execrable adulteration has been lately given in Brande's Journal: — "The journals of Holland have for some time announced, that sulphate of copper, or blue vitriol, was employed in that country to assist in the fermentation of bread; and at the same time that they pointed out the dangerous nature of this substance, they said that it was used because it was supposed to render the bread whiter, more compact, more healthy, and better fermented. The magistrates of Brussels caused thirteen bakers and five druggists to be brought before them for being concerned in this adulteration; and it appeared, 1st, that the employment of the process came from France, and that by the use of *blue alum*, a better fermented and whiter bread was obtained than by ordinary processes; 2d, that the use of the process was announced in the public journals, and in a prospectus which, being printed, was distributed; and stated, that a patent secret for the preparation of leaven was to be sold, but without describing in what it consisted; 3d, that the bakers inquired for the substance under the term of *blue alum*, and that the druggists gave, under this name, blue vitriol, or the sulphate of copper.

"The magistrates decided, that the druggists did not know the use to which the poisonous substance which they sold was to be put, although the frequency of demand, and the character of the buyers, ought to have raised their suspicion; they were therefore discharged: but they condemned the bakers, although they said they thought the substance innocuous, to five days' imprisonment, and a fine of fifteen florins." *

* Brande's Journal, 1829. 198.

It may now be necessary to make a few general observations which relate to all kinds of bread.

In the first place, if the wheat has not been sufficiently dried on the kiln, its flour will never make good bread; the loaf, although of proper weight, will be small, of a foxy colour, and will not be light and spongy. If the wheat, after it leaves the kiln, be not allowed to cool for a proper length of time before it goes to the mill, the bread will appear malty and poor.

New flour never makes good bread; it should lie over for three months before it will be fit for the baker. On the other hand, too much age damages flour. It is a singular circumstance, that flour which, through age, has agglutinated into a hard mass, which, in order to be used, must actually go through the mill a second time, or be otherwise broken-down, and by itself would make very bad bread, will, when mixed with new flour, that, by itself, would make equally bad bread, afford bread of an excellent quality. It is, therefore, the practice of bakers not to use new flour by itself, for the bread would be soft, clammy, greyish, and malty; but to mix with it some one year-old-flour, which remedies all these defects.

If flour has a poor body, and is weak or otherwise bad, the sponge and dough should be made as hard and dry as it can be worked. If this be not observed, and too much water has been used, the fermentation will proceed too rapidly, and considerable risk of souring will be run. In all cases when the dough has accidentally been made too soft, the oven should be cooler than at other times. Too hot an oven would quickly form a hard crust, which, being impermeable to vapour, would lock up the water in the bread.

In warm weather, the fermentation of sponge and dough must be watched with critical precision. If either be left in a state of active fermentation for so short a period above the proper time as even half an hour, there is risk of sourness, and the mass will sink and become heavy.

The shape given to loaves of bread is various, and is indeed a matter of some consequence in point of convenience. In the cities of Great Britain there is not much variation. The common shape is given in the following manner:—after the mass of dough is weighed, it is rolled into a short cylinder, which, being broken into halves, each is moulded into the form of a very thick cake; one of these cakes is then laid over the other, and both are pressed together: the baker with his elbow makes a deep indentation in the middle of the upper cake, which effects the junction of the two parts more perfectly, and prevents the upper surface of the loaf, when it becomes hot in the oven, from assuming an awkward rotundity. But it is essential, in joining the two parts of the loaf, that no dry flour should get between them, as they would then never unite perfectly, and such a loaf would be apt to split. The six-sided shape of a loaf is not given to it in the moulding, but is entirely the result of the contact of the loaves with each other in the oven; each point of contact becomes a side when the loaves swell by the heat.

The possibility of producing good bread depends in a great measure, of course, on the quality of the grain: but not entirely, for some of the accidents incidental to grain may be remedied by art, and good bread made notwithstanding. Mustiness, which is so common a defect, may be remedied by a process as simple and easily executed as it is important. Mr. Hatchett has published a description of a process by which corn tainted with must may be completely purified, with scarcely any loss of quantity, with very little expense, and without requiring any previous chemical knowledge, or chemical apparatus. The following is his own statement:—

"The experiments which I made were confined to wheat, as being of the greatest importance: but there can be no doubt that oats and other grain may be restored to sweetness, with equal success: and I have also additional satisfaction from being enabled to state that the efficacy of the process may be ascertained by any

person, in any place, and upon any quantity of grain, however small.

"From my experiments I am inclined to believe, that must is a taint produced by damp upon the amylaceous part of the grain or starch; that the portion of starch nearest to the husk is that which is first tainted; and that the greater or less degree of must is in proportion to the taint having penetrated more or less into the substance of the grain. In most cases, however, the taint is only superficial; but nevertheless, if not removed, it is sufficient to contaminate the odour and flavour of the whole, especially when converted into flour.

"After various experiments, I found the following method to be attended with success.

"The wheat must be put into any convenient vessel, capable of containing at least three times the quantity: and the vessel must be subsequently filled with boiling water: the grain should then be occasionally stirred, and the hollow and decayed grain, which will float, may be removed. When the water has become cold, or in general when about half an hour has elapsed, it is to be drawn off. It will be proper then to rinse the corn with cold water, in order to remove any portion of the water which had taken up the must; after which the corn, being completely drained, is without loss of time to be thinly spread on the floor of a kiln, and thoroughly dried, care being taken to stir and turn it frequently during this part of the process.

"This is all that is required, and I have constantly found that even the most musty corn, on which ordinary kiln-drying had been tried without effect, thus became completely purified, whilst the diminution of weight caused by the solution of the tainted part was very inconsiderable." *

There is another accident, to which corn is liable in wet seasons, which has sometimes occurred to such an extent as to be felt as a severe and dangerous public calamity. The summer of 1816 was exceedingly wet;

* Philosophical Transactions, 1817. p. 36.

the quality of the grain that year was far below the average; and it was almost universally malted. The bread made from it was exceedingly bad, and its effects on the health of the public were manifest. The attention of Mr. E. Davy, now professor of chemistry to the Royal Dublin Society, was brought to the subject, and his researches led him to a discovery of importance. These researches it will be necessary to enter into at some length: their value, fortunately, is not at present felt; but the knowledge of them cannot be too extensively diffused against the time when we may suffer under the effects of such another infliction.

Mr. E. Davy examined several samples of the new wheat of that year: they had all, to a certain extent, undergone the process of germination. In some cases, the plumula had protruded from about one tenth to five tenths of an inch, and the rootlet from about one tenth to above an inch in length. These were the worst specimens, but in all cases a slight degree of germination was observable. Some crops germinated before they were ready for the sickle, and others after they were made into sheaves.

As the natural germination of the wheat appeared to be similar to that effected by artificial means, in the malting of barley, in which a portion of the farinaceous part of the grain is converted into saccharine matter, he made some experiments to determine this point. Some of the wheat was accordingly dried, ground, and infused in warm water. The infusion, when evaporated nearly to dryness, afforded saccharine and mucilaginous matter. Some flour of the same wheat was similarly treated, and after due evaporation of the infusion it was quite saccharine. The experiment was also made on good old flour, but the quantity of saccharine matter was, in proportion, very inconsiderable.

Some bread made from the new seconds flour, warm water, and yest, was infused in distilled water for twenty-four hours: the clear liquor decanted from it was evaporated, and a portion of saccharine matter was obtained.

These trials rendered it probable that the bad qualities of the new flour were connected with the production of saccharine matter in the grain. This opinion was confirmed by some experiments, in which it was found that by mixing 100 grains of sugar with half a pound of the best old flour, and making it into a loaf in the usual manner, the resulting bread was inferior in taste, colour, and consistence, to another loaf made in the same manner, but without any sugar. Mr. Davy hence concluded, that however necessary the natural sugar of grain may be to the fermentation of bread, if the quantity be increased by artificial additions, or by partial malting of the grain, the fermentation of the dough is retarded, and it does not rise well.

The mode commonly resorted to for improving the ill qualities of this malted flour is drying. With a view of determining whether it is more advantageous to dry the flour hastily or slowly, Mr. Davy tried the following experiments: —

One pound of flour, in a shallow tin dish, was placed before the fire, and occasionally turned over. After twenty-four hours it lost one ounce in weight. The bread from it was of a better colour, lighter, and better tasted than if the flour had not been dried: still it had a disagreeable taste.

One pound of flour, in a tin dish, was placed in a temperature varying between 200° and 230°. It lost two ounces in weight. The bread made from it was in no way improved.

One pound of flour, in a dish, was exposed in an oven varying from 212° to 250° for three hours: it lost nearly an ounce. The bread was scarcely improved.

Hence it appeared that slow-drying was the only way in which the application of heat could be made to improve the flour. Other experiments evinced that during the drying, nothing but water was expelled from the flour.

In trying various methods of improving the ill quality of malted flour, Mr. Davy ascertained that the carbonate

of magnesia of the shops, when well mixed with the new flour, in the proportion of from twenty to forty grains to a pound of flour, materially improves it for the purpose of making bread. Loaves made with the addition of the carbonate of magnesia rise well in the oven, and after being baked, the bread is light and spongy, has a good taste, and keeps well. In cases when the new flour is of an indifferent quality, from twenty to thirty grains of the carbonate of magnesia to a pound of the flour will considerably improve the bread. When the flour is of the worst quality, forty grains to a pound of flour seem necessary to produce the same effect. Care should be taken to mix them intimately together, previously to making the dough.

The following are the results of a comparative trial on the worst new seconds flour, with and without the addition of carbonate of magnesia. Five small loaves were made, each containing one pound of flour, 100 grains of common salt, and a large table spoonful of yest. All the other circumstances relative to making the loaves were the same. The first loaf contained no other addition: the second contained ten grains of carbonate of magnesia; the third, twenty grains; the fourth, thirty grains; and the fifth, forty. After they were all baked in the same oven, the loaves were allowed to cool. The loaf without any carbonate of magnesia had fallen in the oven; it was like a cake, was soft and clammy, and readily adhered to the knife. The loaf with ten grains of magnesia was inconsiderably improved. That with twenty grains was far superior; it was for the most part light and porous; but still there was a slight tendency to heaviness. That with thirty grains was still better. But the loaf with forty grains was uniformly light and spongy, and of a better colour than any of the others.

Mr. Davy ascertained that calcined magnesia produces effects on bread quite the opposite of the carbonate, unless used in a very small quantity, and even then its efficacy was very inconsiderable. In quantity of twenty or thirty grains of calcined magnesia to a pound of flour,

the bread was injured; its colour was bad, and it was clammy. Forty grains even changed the colour of the dough to a pale saffron tint.

In order to determine the comparative efficacy of carbonate of magnesia and other alkaline substances, Mr. Davy made the following experiments. He made fourteen small loaves of the new seconds flour of bad quality: each loaf contained half a pound of flour, and nearly the same quantity of yest, salt, and warm water.

No. 1. Loaf, containing only the above substances; quite heavy, and so clammy as readily to adhere to a knife and the fingers; — bad tasted.

2. Loaf, with ten grains of subcarbonate of ammonia in solution; — lighter and better tasted than No. 1., but rather clammy.

3. Loaf, with twenty grains of solid potash; — better than No. 1., but not so good as No. 2.

4. Loaf, with twenty grains of subcarbonate of potash; — pretty good; rather better than No. 2.

5. Loaf, with ten grains American potash; — improved, but not equal to No. 2.

6. Loaf, with eight grains pure potash; — not so good as No. 5.

7. Loaf, with eight grains pure soda; — inferior to No. 6.

8. Loaf, with twenty grains carbonate of soda; — just as bad as No.1.; quite viscous, adhering to the teeth.

9. Loaf, with forty grains ditto; — better than No. 8., but inferior to No. 2.

10. Loaf, with ten grains pearlash; — improved, but not materially.

11. Loaf, with twenty grains ditto; — tolerably good, scarcely inferior to No. 2.

12. Loaf, with a little pure ammonia; — scarcely improved, clammy, and bad tasted.

13. Loaf, with twenty grains of carbonate of magnesia; — very much improved; better than any of the preceding, light and porous, well tasted, and not in the least clammy.

No. 14. Loaf, with fifteen grains of carbonate of magnesia; — scarcely inferior to No. 13.

When the new flour was well dried, and the carbonate of magnesia mixed with it, in quantity of thirty grains to a pound of flour, good bread was made with the addition of one eighth or one sixth of boiled parsnips, or of baked potatoes. The quantity of magnesia necessary for the improvement of malted flour is so small that it may be used with perfect safety to health, more especially as it probably enters into chemical combination, and becomes soluble. Mr. Davy satisfied himself that the advantages of this invention are certain and important. *

The misfortune which occurred to the corn crops in 1816 was not confined to Great Britain, but extended over the Continent. In France it was so severely felt, that a commission of members of the Royal Academy of Sciences was appointed to draw up an "instruction concerning the making of bread from damaged corn." The following is an abstract of this important document: —

Crops which have been for a long time more or less exposed to an abundant humidity, experience different sorts and different degrees of alteration. In each of these different states they present different results; — to the cultivator in regard to his seed; to the miller in grinding; and to the baker in bread-making.

Wet grain, when heaped up in granaries or in stacks, without currents of air being preserved through the interior, goes speedily to ruin: the humidity does not ascend to the top so as to evaporate; it concentrates in the interior, and hastens the germination which has begun, or rather excites a fermentation which heats and discolours the grain. At times the grain becomes even mouldy.

When the grain of such corn is sent without preparation to the mill, it clogs the mill-stones, and is difficult to work. If the germination is only just commenced, the process is soon completed in the sacks; and the flour

* Philosophical Magazine, vol. xlviii. p. 465., and vol. xlix. pp. 161. 173.

made from it begins in a few days to collect into pieces of such consistency, that it is necessary to pound it with mallets in order to make it workable. Flour of this description is difficult to work, even when very speedily used; and when it gets old, it is impossible to make bread of it without mixing it with some of a better sort.

Grain thus deteriorated always loses part of its natural weight. Thus good grain, of which a certain measure weighs seventy-five, will, if it have commenced to germinate, weigh little better than sixty-one; if greatly germinated, it will weigh but fifty-five; if red-heated, sixty-three; if moulded, without being germinated, fifty-seven. Nothing serves so well as weighing to ascertain the degree of alteration which grain suffers from the effects of humidity.

It is chiefly the glutinous part which is altered in corn which has been exposed to humidity. The gluten almost entirely loses its adhesive powers, and dissolves into a sort of pap or starch, in place of presenting that consistency and elasticity which distinguish flour of good quality, and are of such consequence in the making of bread.

The drying of wet grain is the only means of arresting the progress of its destruction. The most simple mode for this purpose, and that which can most generally be adopted, is to dry the grain in a baking-oven, which is to be met with in most places. The grain may be put into the oven immediately after the bread has been withdrawn: the temperature is then at such a degree that a person may introduce his naked arm without being much incommoded by the heat. After the grain has been thrown into the oven, it should be spread into a bed of from three to four inches in thickness, and stirred frequently in order to facilitate the disengagement of the vapour. At the end of ten or fifteen minutes, according to the state of humidity in which the grain is, it may be withdrawn from the oven: it will then be sufficiently dried; and when exposed to the air, until perfectly cooled, it will have acquired all the qualities

necessary to render it fit for the miller and the baker. The place in which the operation is carried on should be ventilated from time to time.

As the yest is the principal agent in the fermentation, nothing is more important in the baking process, than that it should be procured in the best state. It ought to be such as has been very recently prepared, and on no account more than twenty-four hours old. The temperature of the water ought, in general, to be in an inverse ratio to that of the air; that is, as much colder as the air is hotter, and *vice versâ*. The best flour imbibes about one half* of its weight of water: middling good, from a fifth to a fourth.

The baking of flour which has been made from germinated grain, ought to be proceeded in with much greater rapidity than that of flour from grain in no respect injured: because the gluten of such flour having been more or less destroyed, the process of its fermentation goes on much more quickly. The water employed ought to be cooler in all the operations: the paste should be kneaded more firmly, and divided into loaves of less thickness; the batch should be put into the oven a quarter or half an hour sooner than usual after it is completed; the oven should be raised to a higher temperature; the bread should be only left in the oven forty-five minutes or less, instead of an hour as in the ordinary case; and it ought not to be given out for consumption till two or three days after it has been baked. By attending to these directions, bread will be obtained from the flour of germinated corn, which, without being as good as that made from the best flour, will yet be sufficently salubrious, and of a sufficiently good appearance.

It is necessary to observe, however, that it is only from the flour of such corn as has been very slightly germinated that bread of the above description can be obtained, *unless the corn has been dried before being ground.* But when corn, even greatly germinated, has

* This is much below the estimate of other experimenters.

undergone such previous desiccation, it will yield a flour capable of making much better bread than flour from corn which, though less germinated, has not had the benefit of drying.

Previous drying has not, however, been found sufficient to render grain which has been fired or moulded capable of yielding an eatable bread, or removing the nauseous flavour and acrid taste which distinguish grain thus deteriorated.

It is only by a mixture with good flour that the produce of damaged grain can be turned to good account. By joining only one third of good flour to two thirds of flour from fired or moulded grain, a bread will be obtained of a taste not unpalatable: but it is only by mixing a half, or rather two thirds, of good flour with one third of this inferior flour that the taste of the bread produced is so improved as to entitle it to be considered as good household bread.

It deserves to be noticed, that it is vain to employ a greater quantity of yest, in the hope of improving the fabrication of the bread. The paste, deprived of gluten, is unable to retain the effects of the fermentation excited by the yest. The bread has a good enough external appearance; but in proportion as there has been an excess in the quantity of yest, its consistency is so much the less, and all the bad qualities of the flour, in respect of flavour and taste, are more fully developed.

The mixture of a third of the flour of maize or barley, or potatoes, with a third of good flour, and a third of flour from heated or moulded grain, produces a bread fully equal to that fabricated by the mixture of two thirds of good with one third of damaged flour.

In the process of baking with such mixtures there is no difference from the ordinary mode: it is only necessary to observe, that, in using maize or potatoes, the oven ought to be less heated than for barley or oats, and least so in the case of potatoes. The following mixtures form excellent household bread. 1. One half maize and one half barley, with a leaven of wheat flour one fifth of

the total weight. 2. One half maize and one half wheat flour. A more agreeable and better bread it is impossible to eat. 3. One half oatmeal and one half barley, with a leaven of wheat flour of rather more than one fifth. 4. Equal parts oatmeal and wheat flour. Excellent. 5. Barley flour with one fifth its weight of wheat leaven: bread white and well-tasted. 6. Barley and rye, or barley and wheat, in equal quantities. The last is equal to the best bread of wheat flour alone. 7. Buck-wheat, with an equal quantity of barley or rye, and one fifth of wheat leaven; or, still better, with one half of wheat flour. 8. In general, potatoes may serve, when they are dry, for one half, and, when fresh or new, for two thirds, and even for four fifths, in the fabrication of household bread. This last quantity of four fifths is the greatest that has been employed with advantage, and with uniform success. 9. Oats, barley, rice, or maize, also mix well with potatoes, when used with a wheaten leaven of one fifth of the total weight.

With regard to the foreign substances, such as alkalies, magnesia, alum, sulphuric acid, vinegar, sulphate of iron, gums, &c., which have been used for ameliorating flour, the members of the commission admit that some of them are in a slight degree useful. But they consider such additions unnecessary when simple desiccation of the grain succeeds; and when even the worst flour, if mixed with some good, will afford excellent bread. Such is the information contained in the report of this important commission.

The theory of the fermentation of dough and the making of bread is involved in considerable obscurity. The following comprises almost the whole of what is known of it.

It has already been observed, p. 97, that the fermentation which takes place in dough was once considered peculiar to bread, and hence was named the *panary* fermentation. The chief ground of this opinion was, that if dough in this state be distilled, it does not afford alcohol; although it might have been expected to

do so, if the fermentation which it had undergone were the vinous. But this view of the subject was found to be incorrect, by its being ascertained that infusion of malt, mixed with yest, although it certainly undergoes the vinous fermentation, gives no evidence of its having done so by the test of distillation; for if it be distilled during the beginning of the process, it will not afford alcohol any more than the dough. Beside this negative proof, we have one of a positive nature. It has been found by experiment that dough, when sufficiently fermented, actually does afford alcohol. It is therefore manifest that there is no specific difference between the two exhibitions of fermentation; one is the beginning, the other the sequel: in the one carbonic acid only is produced; in the other alcohol also is generated.

According to the analysis of wheaten flour by Vogel, one hundred parts contain five of a peculiar sugar. We may therefore suppose that the action of the yest, made use of in the process of fermenting the dough, is exerted on this sugar; that it is decomposed; that carbonic acid is formed, and at length alcohol, in the manner already described in the chapter on fermentation, p. 112. The small quantity of sugar present in the flour accounts for the small quantity of carbonic acid evolved in the dough. But there is unquestionably some other chemical change produced; for the bread when finished contains neither of its two chief constituents, the gluten and starch. These two principles are known to exert a chemical action on each other, and to produce saccharine matter. But during the fermentation and baking of dough we do not find that sugar is formed: we must therefore suppose that both the gluten and starch, by their mutual action, are converted into some intermediate state of existence. When sugar is formed by the action of these two principles on each other, it is the starch that suffers the conversion; the gluten is but little affected. But during the change which takes place in the fermentation of dough, the gluten is as much acted on as the starch, and hence its change is as complete. Perhaps the difference in the nature of the change is attributable to the very

elevated temperature at which the chemical action takes place in the oven.

Concerning these changes, the opinion of M. Duportal is, that the yest, after having converted the sugar of the flour into carbonic acid and alcohol, changes the latter into acetic acid; that at the same time the gluten and the albumen are in part decomposed, acetic acid is again produced, some ammonia, and more carbonic acid; and that the starch *uniting* with the undecomposed gluten, there results a compound, the further alteration of which is prevented by the action of fire, which combine these principles still more intimately. This theory M. Duportal conceives to be supported by the following facts: —

"1st, Those farinæ which are deprived of the fermenting principle, or those which scarcely contain any of it, always afford heavy bread, although the saccharine principle forms a part of them; for this substance not being a fermentable principle, it cannot ferment of itself, although it does so by means of a ferment. Thus it is customary to add to the dough a leaven, taken from bread already fermented, or the yest of beer.

"2d, Dough is always acid, notwithstanding that the volatile alkali formed in the operation neutralises one part of the acetic acid, as is proved by the ammoniacal odour of dough treated by potash. Bread itself always contains a little of this acid, which heightens the flavour of it.

"3d, The starch, the undecomposed gluten, and the other materials of the dough, are so intimately united by the baking, that it is no longer possible to separate them. We can discover, by the distillation of bread, an animal matter, for it forms acetate of ammonia; but a less quantity of this is obtained from it than from farina, according to the observations of M. Vauquelin.

"4th, The formation of carbonic acid is rendered evident by the volume which the dough acquires, and by the numerous cavities which are to be seen in it. This gas escaping while the bread is baking, dilates the mass still more, which causes the air to lodge in these cavities,—an important circumstance; whence results the remarkable whiteness of bread full of little holes, so light, delicate,

and sapid, in comparison with the bread destitute of them, which is heavy, compact, and of a disagreeable taste.

"It is, therefore, more particularly the ferment which has the most active share in producing panification. Added to dough in small quantity, the operation is slow and incomplete; in too large proportion, the fermentation goes on so rapidly that it becomes necessary to check it. In this last case, M. Chaptal proposes to knead some carbonate of potash with the dough, which will neutralise the excess of acetic acid. Our good housewives content themselves with uncovering the dough, dividing it, and exposing it to the air, in order to diminish the temperature of the fermenting mass; and this management sometimes succeeds."

The coarser kinds of sugar, along with the pure saccharine principle, contain a ferment proper to themselves. The sugar produced by the action of sulphuric acid on starch is also associated with its proper ferment. There can be little doubt that the saccharine substance obtained by the mutual action of gluten and starch contains a peculiar ferment. Hence, all these kinds of sugar would spontaneously enter into the vinous fermentation. Accordingly we find that wheaten dough spontaneously ferments; and we must attribute the change to the presence of a natural yest belonging to the peculiar sugar which wheaten flour has been proved to contain. The vinous fermentation, when once it has commenced in dough, will proceed into the acetous stage, and from that it will go on to the putrefactive. We can, therefore, be at no loss to understand the nature of leaven. We comprehend why a mixture of flour and water, after some time becomes inflated in all parts with air bubbles; why it turns sour, and finally, fetid. And we can perceive why a piece of this leaven, in a state of active decomposition such as has been described, will induce the same sort of change, almost immediately, in a quantity of dough, which, without such addition, would also have undergone the same subversion of its affinities, but after a greater lapse of time.

Although the sugar contained in corn is associated

with a natural ferment, and although this ferment is found capable of exciting the vinous fermentation in dough, it is not adequate to produce a proper vinous fermentation in watery infusions of the grain. On the contrary, such infusions pass rapidly into the acetous stage. There is evidence, however, of the previous existence of a vinous fermentation, transitory, it is true, but still sufficient to generate alcohol in a quantity that may be appreciated by distillation: but in the case of dough the results are a little different; the small quantity of water present, the obstruction to chemical action occasioned by the stiffness of the paste, and, perhaps, other causes, operate in such a way as to protect the fermentation from the approaches of acetification, and to continue the vinous stage until the operation of the oven puts an end to it.

What the effects of the heat of the oven may be on the dough has never been determined: that they are considerable and important, is manifest from the fact that bread is almost an indispensable article of food, and that dough used as food would be highly detrimental to life.

Water is not merely an agent made use of to wet the flour, and thus promote the chemical action of principles on each other, which in the dry state would remain passive. Whatever quantity of water is employed for making dough, a part only of it is expelled by the heat of the oven, and about one third of the weight of the bread is retained. This portion is somewhat lessened by evaporation, as the bread grows stale, but a great part remains; and we must suppose that it is in a state of chemical combination with the other principles.

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